



The building as a whole

A journey to reflect the concept of sustainable building

Master's thesis for
Master of Science - Architecture

Caroline Mellberg
Creative Sustainability - Architecture
Aalto University - School of Arts, Design and Architecture
Spring 2018

ABSTRACT

The definition of sustainable building design is very often connected with energy efficiency. European Union is one of the big drivers behind the concept "Nearly Zero Energy building", a requirement which all new buildings must meet after the year 2020. There are several other qualification systems that demands figures on noise reduction, indoor climate, sun shading and so on. However, regulations on the material use or diverse ways of construction are seldom mentioned. In this thesis I am reflecting about the popular focus of energy efficiency and going deeper into the understanding of what an ecological sustainable building should be defined as. This is done by interviewing practicing architects within the field and by researching different material properties and building techniques. The findings are visualized through a villa design which is showcased parallel to the research. The design process is influenced by the information gathered in the research process and the final design is the conclusion of my findings. In the end, there is a discussion whether it is necessary to focus mainly on energy efficiency of buildings or if there should be more emphasis on the construction and demolition phase, material usage and maintenance of the building, which are all very critical issues concerning sustainable building design.

A special thanks to
Christoffer Long

TABLE OF CONTENT

Introduction	7
Introduction to Passive strategy and zero energy concept	8
Design process based on analysis of the site and demands on site (regulations, client, EU targets)	11
- Location	
- Detail plan	
- Local climate	
- Program	
- Architectural strategy	
- Landscape adaptation	
- First design sketch	
Research - "How would you define a sustainable building?"	32
Synthesis of interviews	
Design process - Second design sketch	40
Research: Materials	42
- Load bearing construction	
- Floor & foundation	
- Wall	
- Roof	
Research: Building Techniques	68
- Ventilation	
- Heating	
- Water	
- Electricity	
Final design - Presentation, reflection & conclusion	81
References	96
Appendix: Interviews	
- Maria Block	
- Lars-Erik Mattila	
- Kimmo Lylykangas	

INTRODUCTION

Sustainable building design is often mentioned together with passive or zero energy buildings. Both these concepts deal with energy efficiency. To get one of these titles, for your building, there are certain criterion's that the building needs to fulfil. For passive houses the criteria are in space heating and cooling demand, primary energy demand, airtightness and thermal comfort (Feist 2007). Zero or Net Zero energy building concerns the maximum prime energy use and how big share of renewable energy that goes in or out of the building (BPIE 2015). EU has demanded that all buildings must meet a Nearly Zero Energy criterion by 2020 as an attempt to reduce greenhouse gases in the future (Commission Recommendation (EU) 2016/1318, 2.1). Is energy efficiency the only answer to how we can build more sustainable and is it the best way to go? Why do we not talk about efficient material usage, production and transportation of materials, construction work or demolition?

While writing the following pages I asked myself:

- What do I need to think about if I want to design an ecological sustainable building?
- Is it necessary that the building is one hundred percent energy efficient and if so, can this be done by only using healthy materials?
- What are 'healthy materials' and how do they and different building techniques effect the design?

To reflect and visualize these questions and answers I present a design process of sustainable building from above stated starting points. The design of the building develops and changes while getting a deeper knowledge within the three questions above. The end design is a conclusion of my findings.

Introduction to Passive strategy and Zero energy concept

Providing buildings with heating can be done by introducing different HVAC technologies such as heat pumps and electrical radiators. A second alternative is to improve the building's envelope and gain energy through passive heat sources such as sun radiance and excessive heat from users and house appliances. A building envelope is what separates the inside and outside of a building. It consists of for example the roof, walls, foundation, thermal insulation, thermal mass and shading elements. (Suresh, Madala and Boehm 2011)

The fundamental concepts behind passive houses is to create an air tight and highly insulated building envelope where window placement is very important to be able to use the sun as a passive heating source. There is also a need for a heat recovering ventilation system that can provide the building with fresh air since the idea is to keep windows closed to avoid direct heat losses.

In very cold winters, a wood stove can be a good compliment to keep the heat on steady levels. (McGarry 2013)

When constructing this kind of high insulated building, thermal mass is preferred before thick insulation material. Building components with high thermal mass have a high capacity of absorbing, store and release energy under a long time and can therefore regulate temperature in a natural way. Insulation material do not often have the capacity of storing energy and can therefore cause overheating during hot summer days.

The principle of thermal mass works best in large volumes but one alternative to thick walls is the so called 'passive solar wall'. This kind of wall is typically used in cold climates and is designed to absorb heat through a 12-inch thick concrete wall covered in an outer glazing which provides a green house effect for the stored energy. These walls have been given the name Trombe-walls after they were redesigned by Tromble et al. from the original design by E.S. Morse in the 19th century. (Suresh, Madala and Boehm 2011)

There are some critical parts when it comes to designing passive buildings. The lack of natural ventilation and increased insulation thicknesses could lead to an increased risk of mold growth inside the building's structure and around windows and doors. It is therefore important that the mechanical ventilation system does not fail. It is also

important to keep the building parts dry during the construction phase until the outer cladding is installed. (Gullbrekken et al. 2015)

Another problem with this type of system is the lack of understanding human behaviour. For the building's system to work the inhabitants of the building have some restrains. They must for example keep the windows and doors closed and are not allowed to penetrate the building's outer shell with installations such as outdoor lightning since they can ruin the insulation value of the walls by creating cold bridges.

These were the passive house requirements in Sweden 2007 according to Bokalders and Block (2010):

Heat load at 20degree Celsius indoor temperature at lowest outdoor temperature:

12W/m² for detached houses

Maximum bought energy for the total energy supply of a building (climate zone south):

45kWh/m²/year

Building requirements:

Air leakage through the climate shell: max 0,3L/sm²

Windows and doors, U-value < 0,9W/m²K

Floor, walls, roof, U-value < 0,1W/m²K

Noise: at least sound classification B

The 'Zero Energy' concept focuses on energy use. It strives towards buildings that are self-sustaining on their energy consumption. Meaning that they produce the same amount of energy that they are using and are not dependent on energy from the grid. A building that is Plus Energy is producing more energy then what it consumes, and this energy can then be sold to the grid. These buildings are often covered in solar panels or have wind turbines attached to them. The energy production is more important than thick envelopes with a lot of insulation. Since these are both expensive options it is more common to choose one of them.

DESIGN PROCESS

Introduction of the site and
presentation of the client

LOCATION

Kronovägen 12, Mellbystrand
Sweden
56°31'14.8"N 12°57'23.0"E

Mellbystrand is a small village located in the southwest of Sweden. The village is famous for having 'Sweden's longest sand beach' and this makes it a popular place for tourists to visit during the summer season; June, July and August. The village consists of single family houses and summer cottages, owned by people living the rest of the year in bigger cities or in the middle of the country. Mellbystrand has approximately 2.500 permanent inhabitants.

The village belongs to the municipality of Laholm. Laholm is the biggest city in the municipality with 6500 registered inhabitants during the year 2015 (Ingemarson 2017). It is an old city with many small villages surrounding it. The municipality is mostly covered in farmland on the west side and forest in the east. The surrounding cities are Halmstad and Båstad which are both popular summer destinations.

Mellbystrand ('strand' is the Swedish word for beach) is positioned next to the sea of Kattegatt. The Gulf stream brings hot streams from the Atlantic Ocean which provides a steady climate with mild winters where the snow is replaced with rain. The coast climate is windy and hard storms hit the coast line frequently during the winter months from the end of December to February.

Mellbystrand is a strip of villas amongst nature area and forest. It has very clear boundaries that creates a distinctive character to the area. The north of Mellbystrand is limited by a nature reserve, intended to stop the sand from blowing in and disturb the farm land. In the east lies the highway connecting Gothenburg in the north and Copenhagen in the south. In the south lies the neighbouring village Skummeslöv which has a similar character.

Mellbystrand is the second biggest community in the municipality and has both a kindergarten and a low- and middle school. Because of its location next to the highway it has the biggest shopping centre in both Laholm's municipality and the neighbouring south municipality of Båstad, so the inhabitants of the village does not have to travel far to buy their groceries, visit the pharmacy or clothing stores. The village also have its

own health care centre.

The location I have chosen for this project is currently covered in high pine trees, and lies right next to a nature reserve area. Some of the pine trees on site will be removed and used in the construction. There are several local sawmills where the trees can be turned into construction timber by the use of locally produced energy from the saw mill's own biomass.

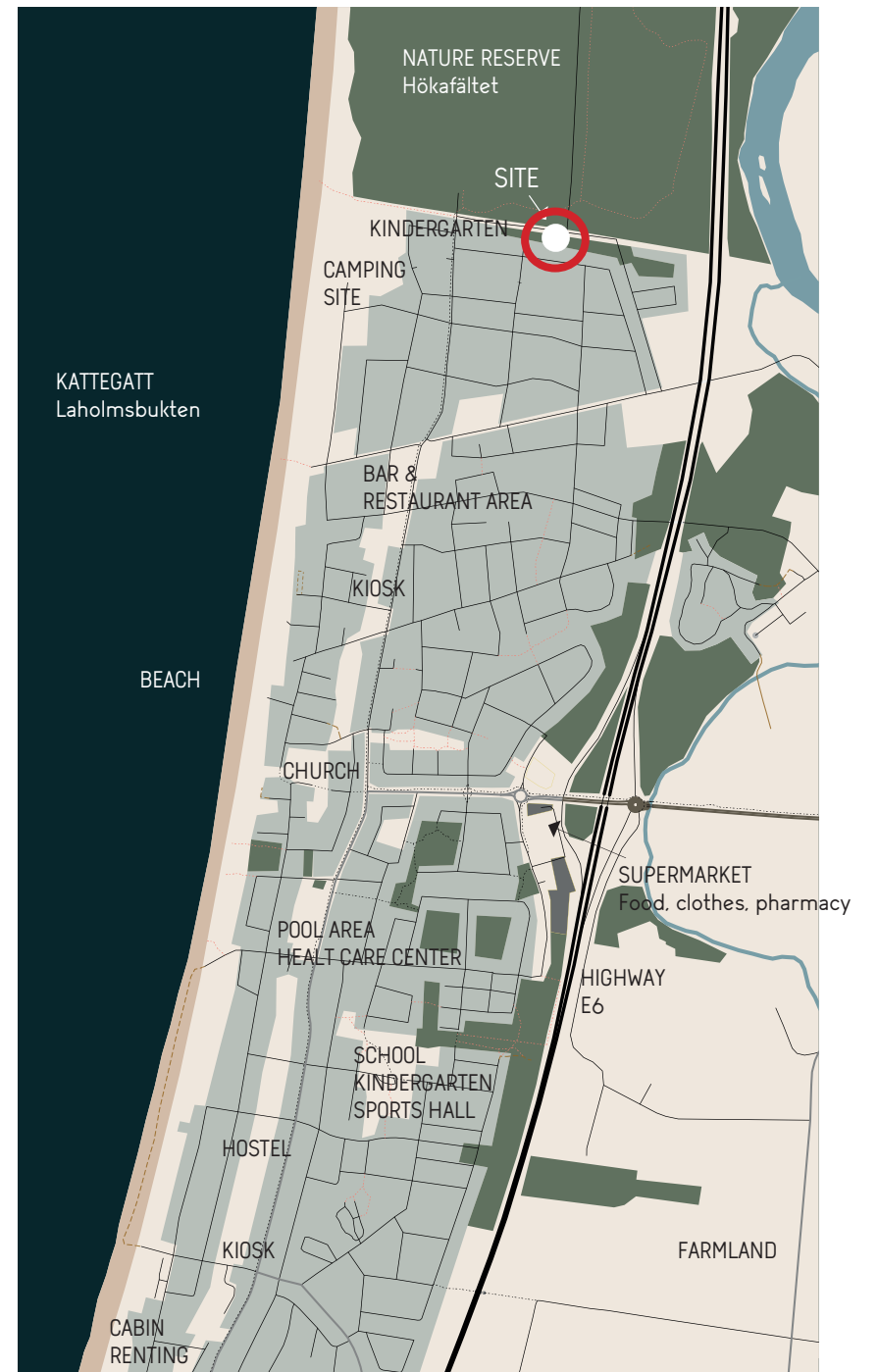
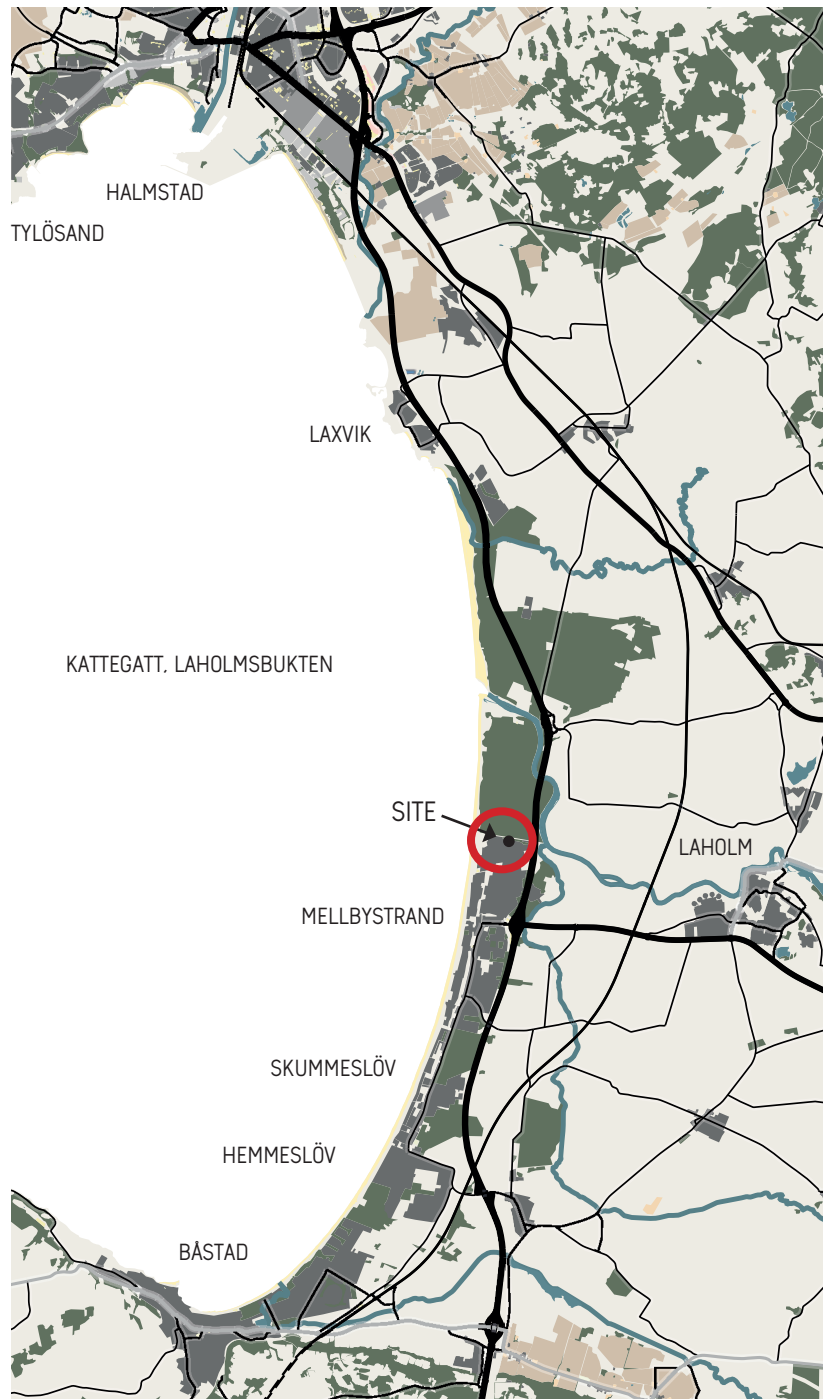
The site has height differences of four metre from the road to the highest point, which creates a good opportunity to use the existing ground as passive insulation by placing the building partly underground.

The neighbouring buildings are summer cottages, and the nature reserve area surrounds the site on the east and northern side. This offers a great deal of privacy during the low tourist season.

I choose this site out of several other potential sites in the area because of its challenging typology and surrounding vegetation.



Northern Europe



REGULATIONS BY DETAIL PLAN

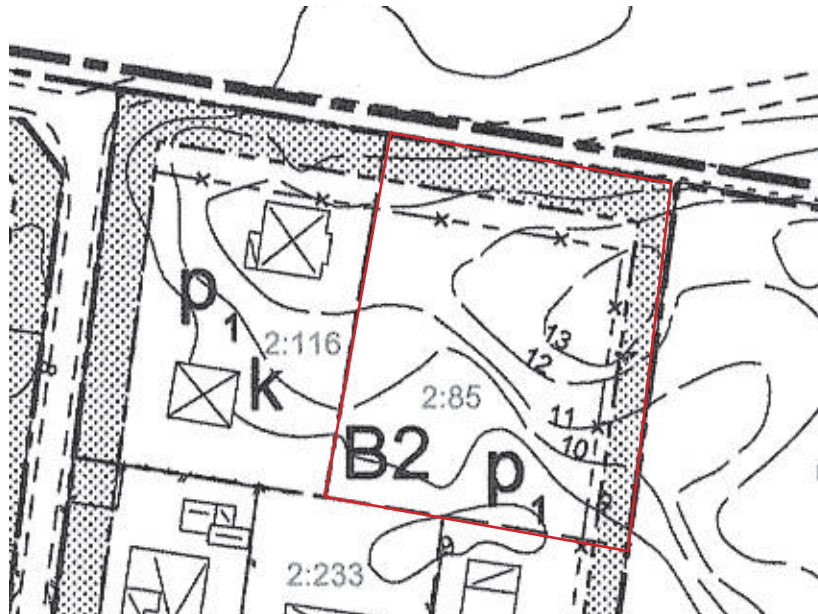


Image 1
1:1000

- — — — Plan area boundary
- — — — Use boundary
- — — — Property boundary
- x-x-x- Boundaries with purpose to expire

These are the building regulations set by the detail plan:

B2 : Residential. Free standing residential building in one floor with furnished attic, no cellar. Only one main building and one outbuilding per lot. Only one apartment per lot. Minimum lot size 900 m². Maximum total building area per lot is 250m² where outbuilding stands for maximum 55m². Maximum height of construction for main building 3,5m, outbuilding 3m. Maximum height for ridge 6.5m. Nature's character and values that are described in the plan description should be paid special attention. If the lot size exceed 1800m² can two main buildings be constructed if this is approved and appropriate.

P₁ : Main building or outbuilding with a purpose of living shall be placed at least 4,5m from the boundary of the building plot against the neighbouring lots. Outbuilding shall be placed at least 3m from the boundary of the building plot. Garage can be placed 1,5m from the boundary if there is no other place available on the lot.

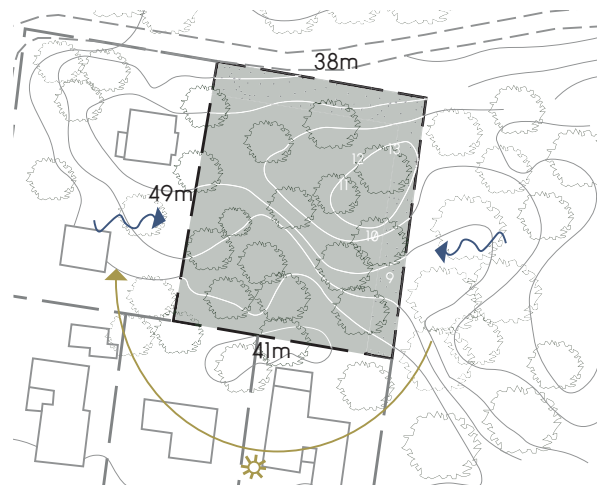
k : The building is covered by the 3 chapter 10 paragraph PBL. Modifications shall be performed with care so that the building's character and value are taken into consideration.

Source: Stadsbyggnadskontoret (2017)

LOCAL CLIMATE

The area has a coast climate with an average temperature of 7,4°C. The climate is steady with the average high temperature of 10.6°C and the lowest of 4.3°C (Climate data). The site is surrounded by trees, less dense in the southern and western direction. Since the main wind direction is west to east, these trees will slow down the wind. The average annual precipitation is 739mm and the 173 days with precipitation is spread during the whole year with a peak in the summer months July and August (Climate data). 21st of June is the day when the hours with sun peaks before it gets darker again. During the winter months the sun sets at four in the afternoon and does not rise until nine in the morning. In the summer the sun does not set until eleven in the evening and rise again at six (Sunearthtools). The average sun angle, and the most efficient one for sun panels and sun collectors, is 45 degrees.

This weather analyse shows that it is important to shelter the building from wind and rain in the east and west direction. It is also important to maximize the intake of sun light during the winter season in south and to be able to shelter the windows from long hours of sunshine in summertime.

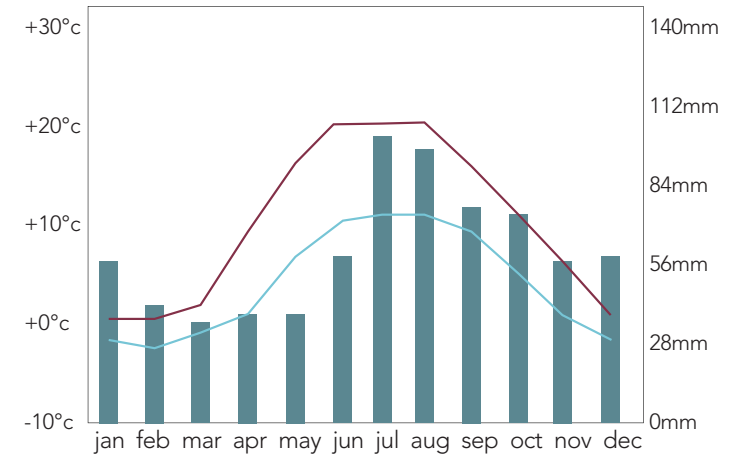


Yellow arrow: Sun path
Blue arrow: Main wind directions 1:1000



CLIMATE CHART, Halmstad

Image 2

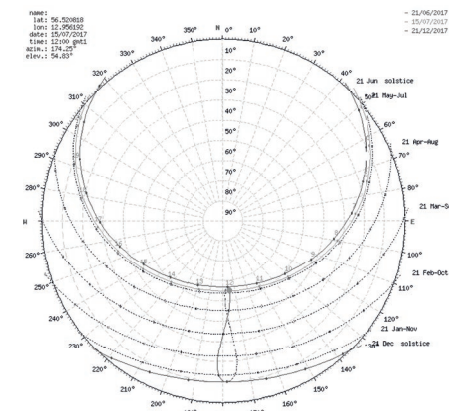


Annual average high temperature: 10.6 °C
Annual average low temperature: 4.3 °C
Average temperature: 7.4 °C
Average annual precipitation: 739 mm
Days per year with precipitation: 173 d.
Average annual hours of sunshine: 1928 h.

Source: <http://www.climatedata.eu>

SUN PATH, Mellbystrand

Image 3



ANALYSING COMFORT ZONE STRATEGIES

To get a more detailed analysis of the climate and to find out which design strategies that would be most efficient in this area I used the program Climate Consultant (Informer Technologies, Inc. 2017) to collect the climate data.

By using weather data from the website Energyplus.net the programme generates a psychrometric chart which shows an area where the human comfort zone is reached in terms of temperature and humidity. The programme also proposes distinctive design strategies on how to reach this comfort zone and to which extent they are effective. I have used this information as a guideline in my design work.

The analysis is based on outside weather and climate conditions in the specific area. The psychrometric chart draws an area which describes a range of values considering which temperature and relative humidity the indoor air should have to make a human feel comfortable. In cold countries for example the indoor air should be colder and more dry than in a hot and humid country to make us feel comfortable and stay healthy.

Explanation of the psychrometric chart generated by the computer program Climate Consultant (image 4):

The blue area of the chart shows when the comfort zone is reached without any extra help from heating systems or sun shading equipment. This is when the outside temperature is between 20-24°C. When the temperature rises above 24°C sun shading is needed to avoid overheating of the building. If I would choose a strategy where I focus on the implementation of thermal mass, this would be most efficient from 22°C and upwards. If the temperature is no colder than 13°C the comfort zone can be reached with internal heat gains, such as household machines and human activities. Below 8°C wind protection of outer spaces is needed. From 0°C and upwards the comfort zone can be reached by using passive solar direct gain on low mass and below that extra heating is needed. To reach the comfort zone during the entire year all these strategies are needed according to the program Climate Consultant and the division among the 100% comfort hours are:

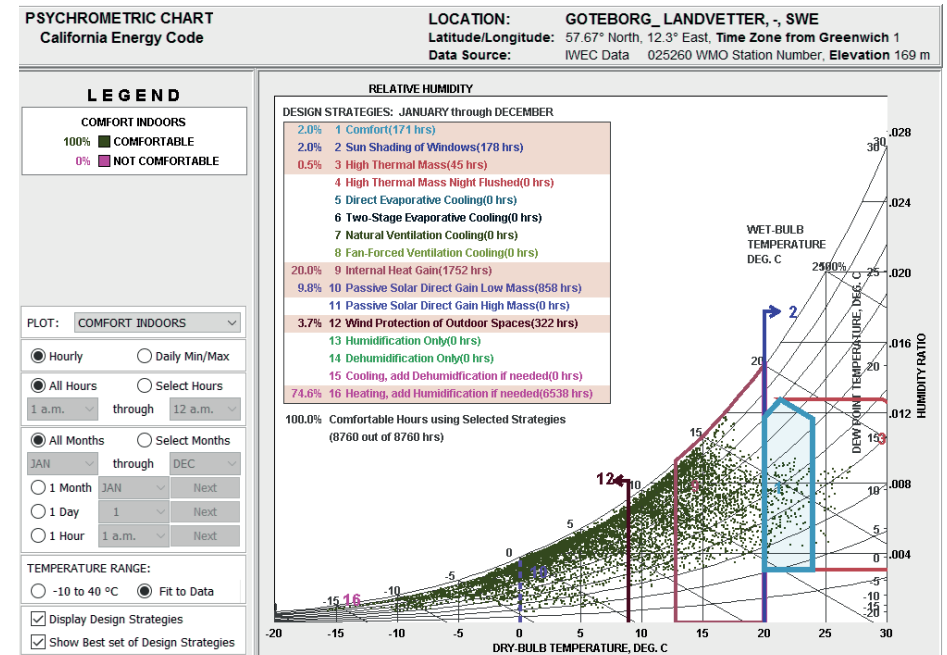


Image 4

- 2% comfort zone
- 2% Sun shading of windows
- 0,5% High thermal mass
- 20% Internal heat gain
- 9% Passive solar direct gain low masses
- 3,7% Wind protection of outdoor spaces
- 74,6% Heating

These numbers shows that the biggest percentage of reaching the comfort zone during the entire year is given by heating. Because of this the biggest focus should be to implement a good heating source and to make use of the internal heat gains by for example implementing a heat exchange ventilation system. High thermal mass is the least efficient strategy to use when reaching the comfort zone in this area and should therefore not be the main source of providing extra heat.

PROGRAM

Requested rooms

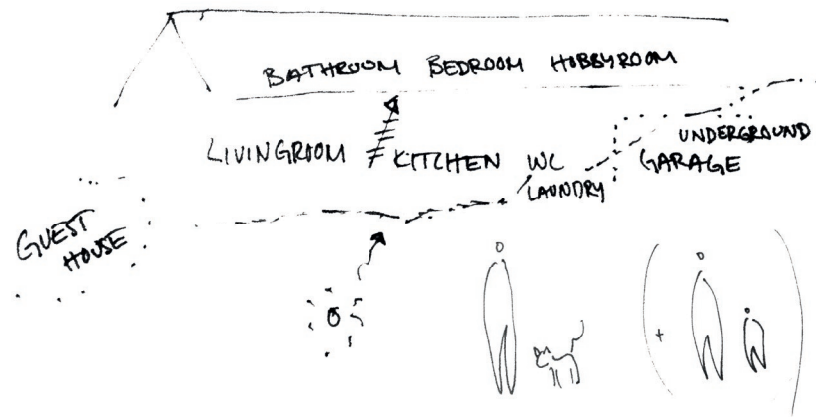
1 Bedroom	1 Enclosed kitchen
1 Hobby room	1 Living room
1 WC	1 Guest house
1 Bathroom	1 Garage
1 Laundry room	

CLIENT

The client is a 25 year old woman buying her first house. She does not own the chosen site but represents a client with certain needs that the building should fulfil. The client has mainly been involved in the first stage by giving me input so that I could develop a program. I have then freely developed this program further but kept the required spaces.

Her requirement is that the building should be planned for a family of 1-3 people. She wishes to have one bedroom, one hobby room, a semi separated kitchen, living room with big windows from the floor to the ceiling, two bathrooms, one smaller guest toilet and one bigger bathroom. She likes the 'industrial style' and wants the house to be floor area efficient, meaning that the room should not be bigger than what the intended activity demands.

The sketch below shows how she wishes the rooms to be disposed.



Photograph of the building site, 5pm March. View from the road



View from the middle of the site looking south

DESCRIPTION OF INITIAL DESIGN STRATEGY

The initial design strategy is inspired by the fundamental ways of designing a passive house (focusing on the position of the building, sun energy and the shading of it) since I have been taught that this is the most efficient and ecological sustainable way to compose a building.

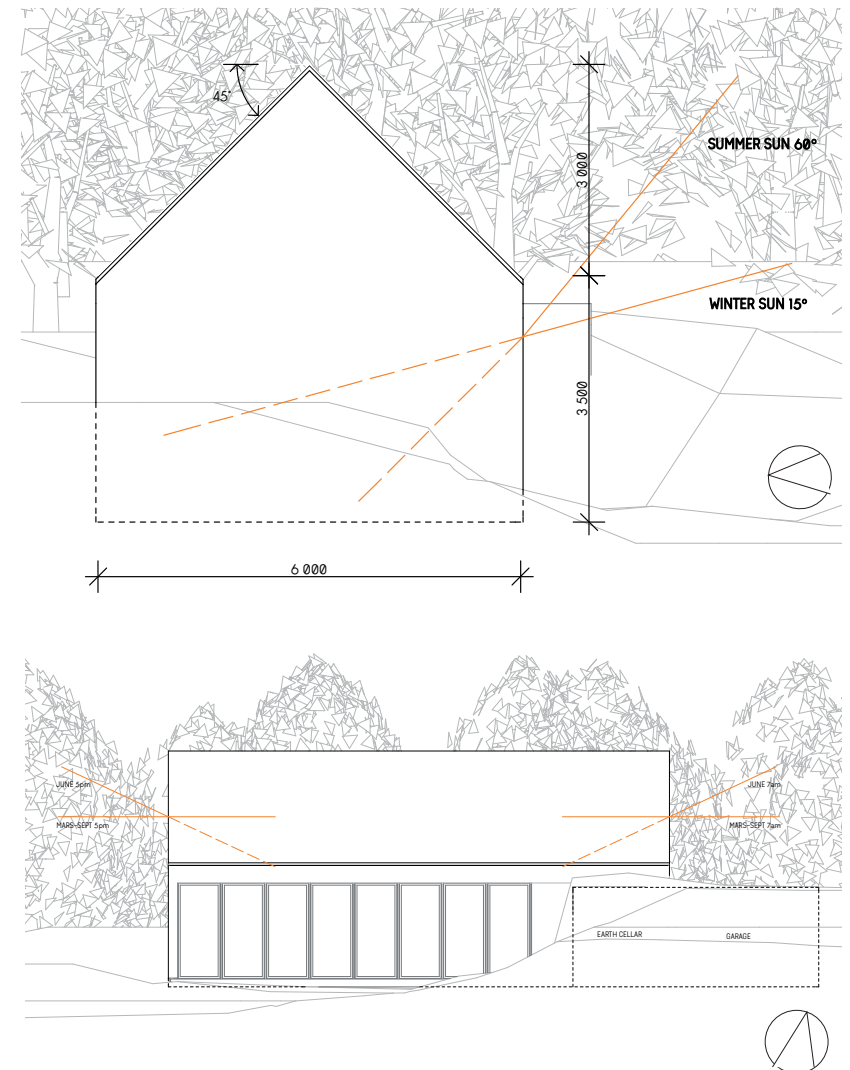
Starting from analysing the sun path over the location shows that the most efficient roof angle for solar panels and collectors would be around 45 degrees. It is as well the most efficient degree for getting the most out of the building height which is regulated by a 45 degree line from the maximum building height which is 3,5m. Therefore a 45-degree angle on the roof would be the wisest one to use even if solar technology would not be used. Personally, I would also argue that it is the most aesthetically appealing one. The maximum allowed height for the ridge is 6,5m according to the detail plan.

I would like to keep the terrain as much as possible intact and place the building into it. The earth will then protect the building from wind and fast temperature changes.

The building will get direct heat gain from the sun by placing the windows on the south facing walls. The living areas will therefore be arranged in such a way that they will get maximum sunlight throughout the day.

The building will be designed so that the air can move freely through the main living areas, without being disturbed by separating walls.

The entrance should be enclosed so that the cold air will stay in the hallway and the entrance door should also be protected from wind on the outside.



Initial main design strategy

Seen from south direction with windows covering the south facade and with the garage placed underground. The orange arrows show the sun angle in summer and winter.

LANDSCAPE ADAPTATION

By adapting the building to the landscape many positive effects will come for free such as wind sheltering, insulation from the ground, natural drainage and free heating from the sun.

The sun provides heat, light and shadows. Wind comes with fresh air and ventilates spaces. Height differences in the terrain can be integrated in the building design to provide shelter and insulation. Water ponds can be arranged for draining the ground and chill the air. All plants work as wind breakers and they will also drain the ground from excessive rainwater. Dense bushes gives cover to the ground and an espalier mounted on a wall can work as an extra insulation layer as well, with more or less effectiveness.

Storm-water management is a crucial part. In case of heavy rain the local waste water treatment can flood and particles injurious to one's health can be exposed. It is therefore important that each household have a good drainage system, so they can take care of all excessive water and release it slowly into the ground and the greenery on site; instead of leading it to the local system together with polluted water from the roads. (Sternberg and Lanne 1992)

Storm water treatment can be done in several ways. Any hard surfaces can be tilted so that the water will run off or be perforated so that the water can go through. For the best drainage a perforated surface should be placed upon macadam, which have both a load bearing and draining function. All plants and growing media contribute to delay and cleaning of the rainwater. The roots bind the ground and creates holes in which the water can run through. Trees and bushes takes care of the water before it hits the ground. Next to areas which are more sensitive to water, such as the patio with a wooden floor, a ditch should be arranged and filled up with a porous material or gross macadam to let the water go through without creating open holes in the landscape.

Plants should, besides from being arranged for aesthetic or practical reasons, be considered for their ability of providing edible fruits, vegetables, herbs or beans. Composting from food and fallen leafs during autumn can be used as a fertilizer to grow new food when the spring comes. If there is a possibility to grow food this should be considered since it does good for both the soil and the planet.

The existing landscape on the site has a lot of height differences and I

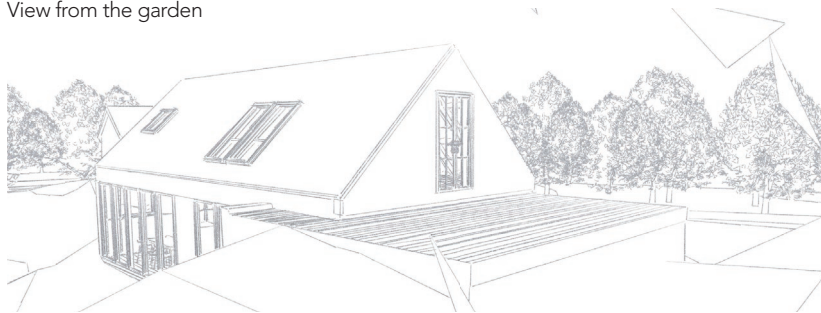
want to take advantage of that extra surface in my design. To cover the building in earth is an old traditional way of creating extra shelter and insulation. The advantage of integrating a building with the surrounding ground is that the earth is a natural moderator of temperature. Below the frost line the temperature remains constant and it is close to the area's annual mean temperature. This result in an extremely stable year round temperature compared to a building above ground. The heat on the surface changes by the season but the heat gained in the summer can last until early winter. In the same way the coldness from the winter will last and chill the building until the summer. What effect it has on the whole buildings heating demand depends on the area of coverage. (Pearson 1989)

FIRST DESIGN SKETCH

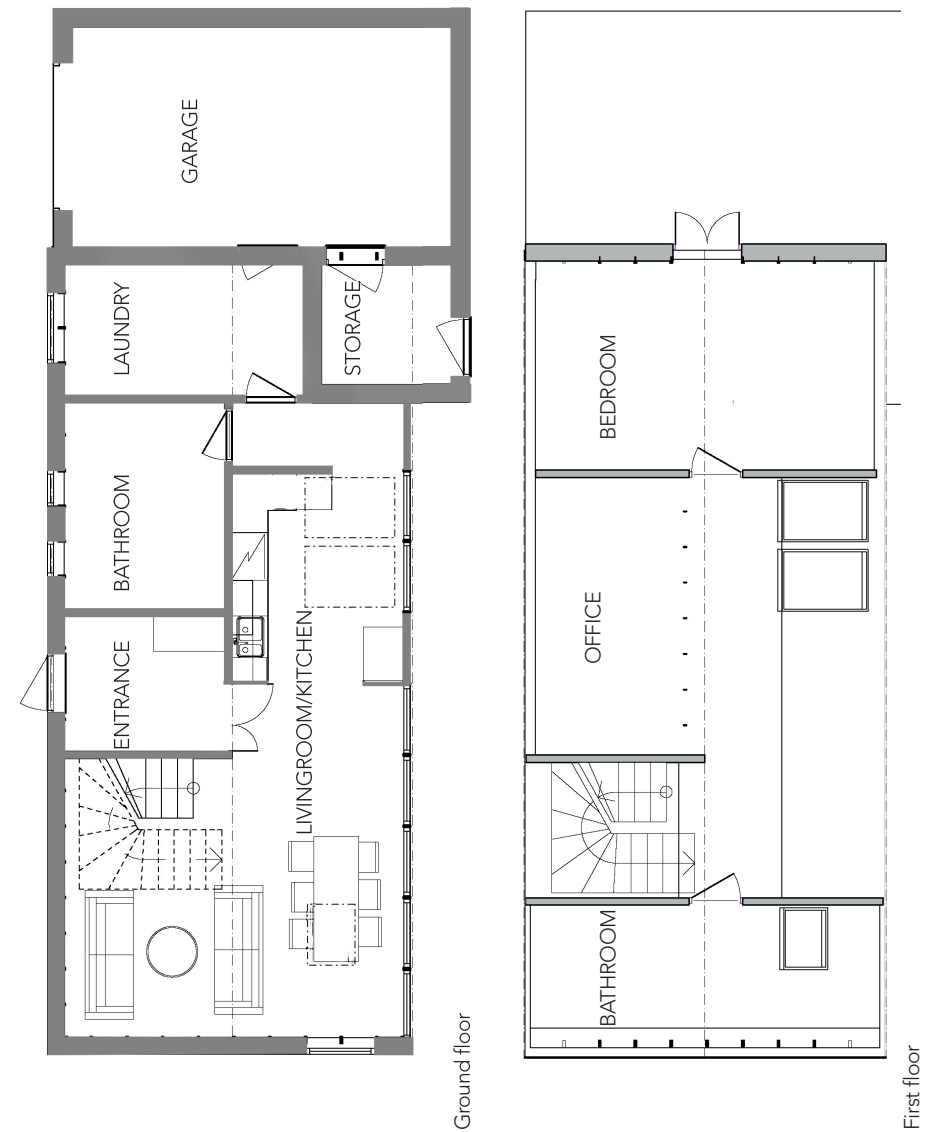
This first design proposal builds on my previous knowledge of energy efficiency, the knowledge of the site, surroundings, climate and the client's request of spaces. It is a compact building with a long body that maximizes the intake of sun light on the southern wall. The reduction of angles and envelope surfaces reduces the heat losses. The garage is placed underground and the western side is partly underground. The more public spaces are placed on the ground floor while bedroom, office and bathroom is placed on the first floor. Living room and kitchen is positioned on the south side to reduce the need of windows facing north. The intermediate floor does not cover the whole floor area upstairs but lets the air flow freely through the building. Windows are placed on the roof to ventilate excessive heat during hot summer days. An enclosed entrance prevents the hot air to escape.



View from the garden



West view, bedroom door



RESEARCH

“What do I need to think about if I want to design an ecological sustainable building?”

“How would you define a sustainable building?”

Synthesis of interviews

A sustainable building can be defined in many ways depending on who you ask. Legislation and regulations often focuses on energy efficiency while some architects define their building as green by giving it materials that can sustain for a long time without maintenance, whether the materials are produced in an efficient and healthy way or not. It is therefore hard to define what an ecological sustainable building is and what potentials it has. To get a clearer view of this issue I interviewed three practicing building architects that are all defining their work sustainable in one way or another. The three architects were Kimmo Lylykangas (building architect and lecturer, Helsinki), Maria Block (building architect and author, Stockholm) and Lars-Erik Mattila (building architect, carpenter and lecturer, Helsinki).

In autumn 2015 I interviewed Kimmo Lylykangas. It was my first semester as a master student and I was curious about the concept of Zero energy- and passive buildings. I had heard about the concepts before in some lectures, but I did not know what the difference was. I thought they were both aiming for the same thing and believed that this was the only right way to go. To gain more knowledge I asked Lylykangas for an interview. Kimmo Lylykangas is a Finnish architect and he is famous for his passive houses and lectures in the subject. By then he worked part time with teaching in both Aalto University and Umeå University in Sweden.

The second person I interviewed was Maria Block in May 2017. Block is a Swedish architect and author. She is a co-writer of the book “The whole building handbook: How to Design Healthy, Efficient and Sustainable Buildings” which I have used frequently while researching the topic for this thesis. Since I found the book so interesting an interview with the writer was a must. Maria Block is specialized in ecological and healthy buildings and how to avoid hazardous substances in buildings.

The last person for an interview was Lars-Erik Mattila which also took place in May 2017. I came in contact with Mattila through the course “Sustainable Building Design” where he was one of the teachers. He has been recognized for his thesis work where he designed a multi storey apartment building with focus on passive strategies, natural ventilation and organic materials. Mattila is interested in restoration and the metabolism of old buildings and how they can inspire new building techniques.

All three interviews can be found in the end of this book.

What was especially interesting was that all three of them had different opinions about what a sustainable building should be like.

Maria Block often mentions the words ‘hormone hazardous substances’ as the most important thing to consider when constructing a house. She also cares about choosing right materials that can breathe and to choose finishing, such as paint and surface treatments that does not contain hazardous substances. As a contrast to Lars-Erik Mattila, which is a bit more “conservative” in his materials, Maria is not afraid to use new materials on the market and she gave me tips of for example Hasopor and Koljern which are two types of foam glass. It is not an organic material, but it is produced by renewable materials and have very good insulation properties and a long lifespan.

Mattila is instead talking about pure materials with minimum processing and how to combine a minimum amount of different materials. He believes in simplicity and how the buildings were made in the beginning before we had specialized materials, energy technology and mechanical systems.

Lars-Erik Mattila:

“I do the food analogy; you can make excellent simple good food without touching processed food. If legislation only leads to make processed food and if your education as an architect or your situation at the moment is about choosing frozen pizza or ice cream and trying to put these together, you can check that they have enough energy and enough calories, they are suppose to be good, but how can people then still be fat?”

However, all three of them are, sceptical about the concept of zero energy and passive buildings. They all agree that legislation is steering the construction of buildings in the wrong way. Lylykangas who himself have drawn several passive buildings are very critical to the concept. He talks about how the idea of a passive building originated from the idea of how to lower energy bills. It was not a concept to limit green house gases in the beginning. The figures that must be reached to earn the label is still based on economy. It does not matter how you save energy and what materials you use as long as you reach the energy figures. Passive houses have been getting a status of sustainable and ‘green’ buildings

and the same applies to Zero and Plus energy houses which have the same original idea but these buildings are also suppose to produce their own electricity.

Kimmo Lylykangas:

"My understanding is that the whole point of why we talk so much about zero energy is that it is a European strategy. They want to respond to the climate change not only by making better buildings but also supporting the industry. To develop better products as photovoltaic panels and other technical gadgets, with which you could in a way play this game. And they think it is a boost for the economy when the industry develops new products. More viable thing would be just to say; 'Hey we would somehow need to reduce our consumption'. Now we are saying that 'yeah yeah we are keeping on consuming and we develop products which will solve it'. It would be wiser to accept that we will be so many on the planet that we cannot keep on consuming this much. There will be things in technology but we cannot fully count on technology to solve all the things. I would rather look at the family and households how we can be better and how the built environment can help us consume less."

The European Union has decided that all new building should be 'Nearly Zero Energy Buildings' by the end of 2020 and all new public buildings have to be this by 2018. EU define a NZEB like this:

'...means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby'

(Commision Recommendation (EU) 2016/1318, 2.1)

EU is specifically pushing on the production of on-site energy, if this energy production would not be sufficient than there has to be more demanding requirements on the building's energy performance (EU 2016). Lylykangas is critical to the on-site energy production and argues that not all buildings are placed in good positions for solar panels. Instead the production should be taken care of professionals which can place all these pv panels in a solar effective position and whom also knows how to maintain them in a correct way. Instead we let building owners pay for expensive technology which will be poorly maintained and loose its

efficiency in a shorter amount of time.

Block believes that legislation is the right way to go to make architects and builders aware of the problems we are facing in today's unsustainable building industry. The problem now is that legislation is focusing on the wrong issues and it tricks people to believe that they do good.

Maria Block:

"I do believe in legislation. But these environmental classification systems... Many builders want to have a certificate so that they can sell their building more easily. Others do it because they are engaged and wants their grandchildren to have an enjoyable time on earth. The systems have not been good enough when it comes to material decisions. They are more focused on energy, daylight, radon, legionella etc. The demanding's concerning materials are very low. You could build almost anything and still get an environmental classification of silver and sometimes even be classified with gold. Since there has not been any demands on electricity and plumbing the classification is misleading. People believe they buy a highly environmental classified building and believes they do good. The buildings are better than others in some ways but they can still contain a lot of hazardous materials."

The classification system of gold and silver which Block refers to come from the organisation Sweden Green Building Council and it is called 'Miljöbyggnad'. The building can be classified in three various levels: gold, silver and bronze. A building which gets the status Gold is seen as a success and a highly sustainable building. As Block tells, there are many things which are taken into account but material is not one of them. The building must fulfil requirements within for example energy and heating systems, noise, daylight, radon, indoor climate and legionella. (Sweden Green Building Council)

Mattila is also questioning the legislation. He argues that the fundamental flaw in legislation today is that it is only interested in the momentarily energy use and does not take into account the energy that was used to create the building and which will be needed to maintain it in its lifetime.

Lars-Erik Mattila:

"Buildings reflect the legislation, of course, that is what the legislation are meant for. But if the legislation is screwed or there is something wrong with it, it will show up in the buildings and that is what we have in the moment. And it is not only that, according to the legislation it is also illegal to build in a different way. What makes this almost humoristic is that we have buildings today, that work in a totally different logic; the old buildings. Those buildings at this moment are not taken into consideration. Even though they can be proofed to be very energy efficient."

Mattila takes his own design as an example. A building which will be built consisting of only five materials; wood, stone, glass, lime and steel. The building will not have conventional wall insulation and it will operate by natural ventilation. Because of the Finnish legislation this building will not be legal and instead they have to apply for a special experimental building permit. Natural ventilation is considered bad because it is not energy efficient enough. One can wonder if a mechanical system driven by electricity is more energy efficient in the long run. Natural ventilation is a standard solution for old buildings but are now considered unsuitable.

To conclude these statements the main issue here is the obsession with energy efficiency. Which is not always motivated by creating sustainable buildings but also to make them as cost efficient as possible. The politicians are not concerned by how it is made but rather how much money that can be saved by putting the management of energy into the hands of the builders.

Lars-Erik Mattila:

"The buildings are now tools to make money, within restrains of legislation and with makeup of ecological crap so that people will think that it is good."

The behaviour of advertising false 'green' products is called Greenwashing. This is when a company claims to be green as an attempt to hide the unpleasant fact of their not so otherwise green practice. A building can be called green because it is very energy efficient. What is not taken into account is the not so environmentally friendly glass wool insulation which requires a lot of energy to produce and which cannot be reused when the building is demolished. Even though these products are often advertised

as green by the company because of their durability and that there is no need of maintenance if the building stays intact. Greenwashing makes it hard for consumers and builders to know what really is ecological sustainable.

According to these three interviews there are no easy answer to what an ecological sustainable building look like but wood seems to be a key ingredient to use in Nordic buildings. Wood can be used in many ways, as construction timber, insulation, wind stopper, surface cladding and so on. It can also be used for heating of water and the air. Wood is considered climate neutral because it binds carbon dioxide when it grows and releases the same amount when it incinerates. What must take into consideration though is the energy used for the production and transportation.

Concrete and bricks can also get a green label sometimes because of the materials durability and minimum need for maintenance.

Kimmo Lylykangas:

"Well we are now demolishing concrete buildings which are 30 years old, but if you can make them last 200 years then we start to talk about real benefits. But I think you can make a wooden house also last for 200 years. Bricks are made in a very energy intensive production but after that it can last for a really long time. I have been doing research on this and things are never black and white, they are not that clear as you might think they are."

DESIGN PROCESS

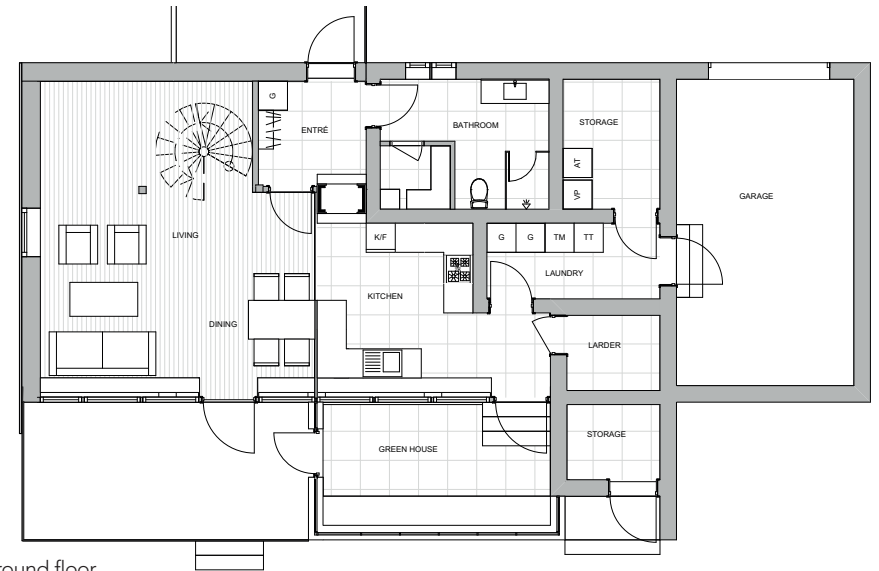
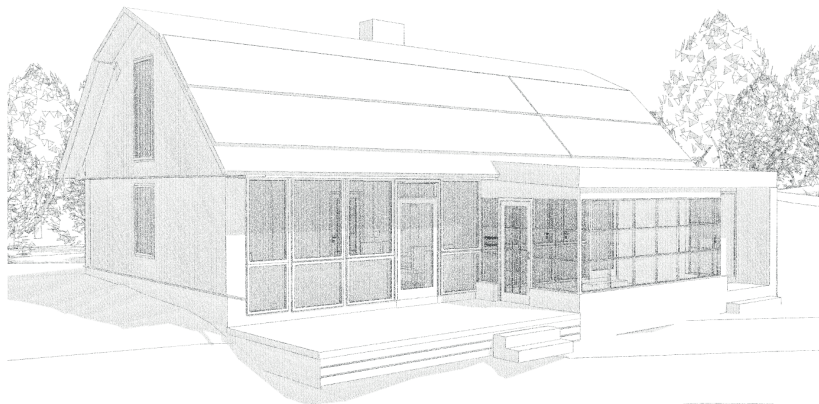
Developed design

SECOND DESIGN SKETCH

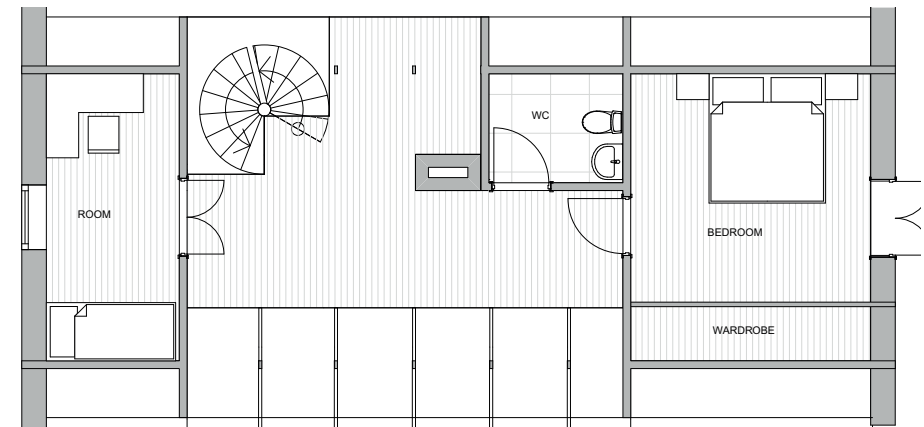
This second design sketch was developed alongside the researching of different materials and building techniques which will be presented in the next chapter.

The building still consists of a long body with two storeys. The windows in the south are constructed as a solar wall and the green house preheats the air and shelters the building from direct sun. A cool ventilated larder is connected to the kitchen and the building is divided into 'wet' and 'dry' areas. After researching materials I was able to estimate a realistic thickness of the roof and walls (due to insulation and construction). This lead to a reduction of ceiling height on the second floor which then caused a cramped feeling to the rooms. The new shape of the roof is a result of trying to prevent this.

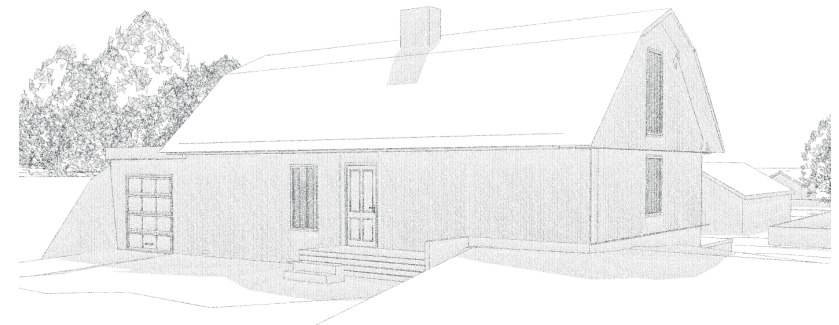
When I was finished with the interviews I realised that I needed to change my priorities. Should the compact and energy saving envelope restrict the atmospheres of the living areas, which is already restricted by the detail plan? Is not the humans well-being more important than an energy efficient shell? A building where a family could grow and shrink over time is a sustainable way to tackle the needs of the future. It reduces both the need to move out and also to renovate and add new bodies to the existing building. The next step from here is to think about how the building could be reshaped to create interesting spaces and micro-climate zones. By doing this the building will instead work together with the outside climate instead of against it.



Ground floor



First floor



RESEARCH

“What are ‘healthy materials’ and how do they and different building techniques effect the design?
Which ones do I choose for my building?”

Load bearing construction

The building's construction will mainly consist of wood. It's a natural choice due to the climate and resources of the Nordic countries. The total area of Sweden is 40,8 million hectares and 22,5 million hectares is generative forest. The number of trees that are being planted is larger than the numbers of trees that are being cut down. This have been the case for the entire 21th century according to Svensk Trä's publication "Att välja trä" (how to choose wood) written by Bergkvist and Fröbel (2013). Sweden has a legislation that protects the forest and demands re-plantation of trees to have a sustainable forestry industry (Skogsvårdslag. SFS 1979:429.)

Wood is therefore the best material to use when constructing one to two story high building on this specific location.

Using wood in construction is also a climate neutral alternative (if only referring to the material itself). A tree is binding an average amount of 1ton carbon-dioxide and producing 0,7ton oxygen during its lifetime. The wood is therefore a carbon-dioxide storage, and this will not be released until the wood is burned in the end of its lifetime. The burning of wood creates heat and electricity and the emissions will be equivalent to what the tree was binding during its lifetime. Wood will therefore not create any extra emissions except from the harvesting, production of boards and transportation from the forest, to the sawmill and in the end arriving to the building site. The main energy source used in sawmills are usually created by the sawmill's own biomass and only 20% stands for external electricity. (Bergkvist and Fröbel 2013)

The forest of Sweden consists of 83% coniferous forest, 5% deciduous forest and the rest is a mixture between the two. Pine tree stands for 39%. The protected nature area in front of the site were planted with pine trees to bind the sand and to stop it from spreading over the farmland. Pine was optimal because they thrive in a dry and barrel landscape. The biggest percentage of all wood is spruce (42%). Softwood as pine and spruce are most commonly used in construction while hardwood (deciduous timber) is mostly used for interior furnishing, furniture and floors (Bokalders and Block 2010).

The building site is today covered in a large amount of pine trees. Many of them must be removed to allow space for the building and by using them in the construction there will be minimum waste from the first construction phase.

Floor and foundation

The choice of foundation depends on the building type and the ground's typology, load bearing capacity and moisture content. It is important to avoid moisture and the risk of moulding. For ecological reasons the interference with the ground should be minimum. This can be hard to fulfil sometimes and consideration of what is best for the nature and for the building is essential. A slab can be many times better than a suspended foundation when it comes to ventilation and moisture threatening even though a suspended foundation will make less harm to the ground and the living beings in the surrounding area.

Constructing a slab is one of the most common construction methods when building a foundation for small residential buildings. The construction of the slab is crucial to avoid moisture damage. The slab should be placed upon dry and clean shingles and the insulation should be placed underneath the slab to keep it warm and dry. Insulation should also be placed along the sides of the slab and extra ground insulation around the building is a plus to avoid cold air to reach the foundation.

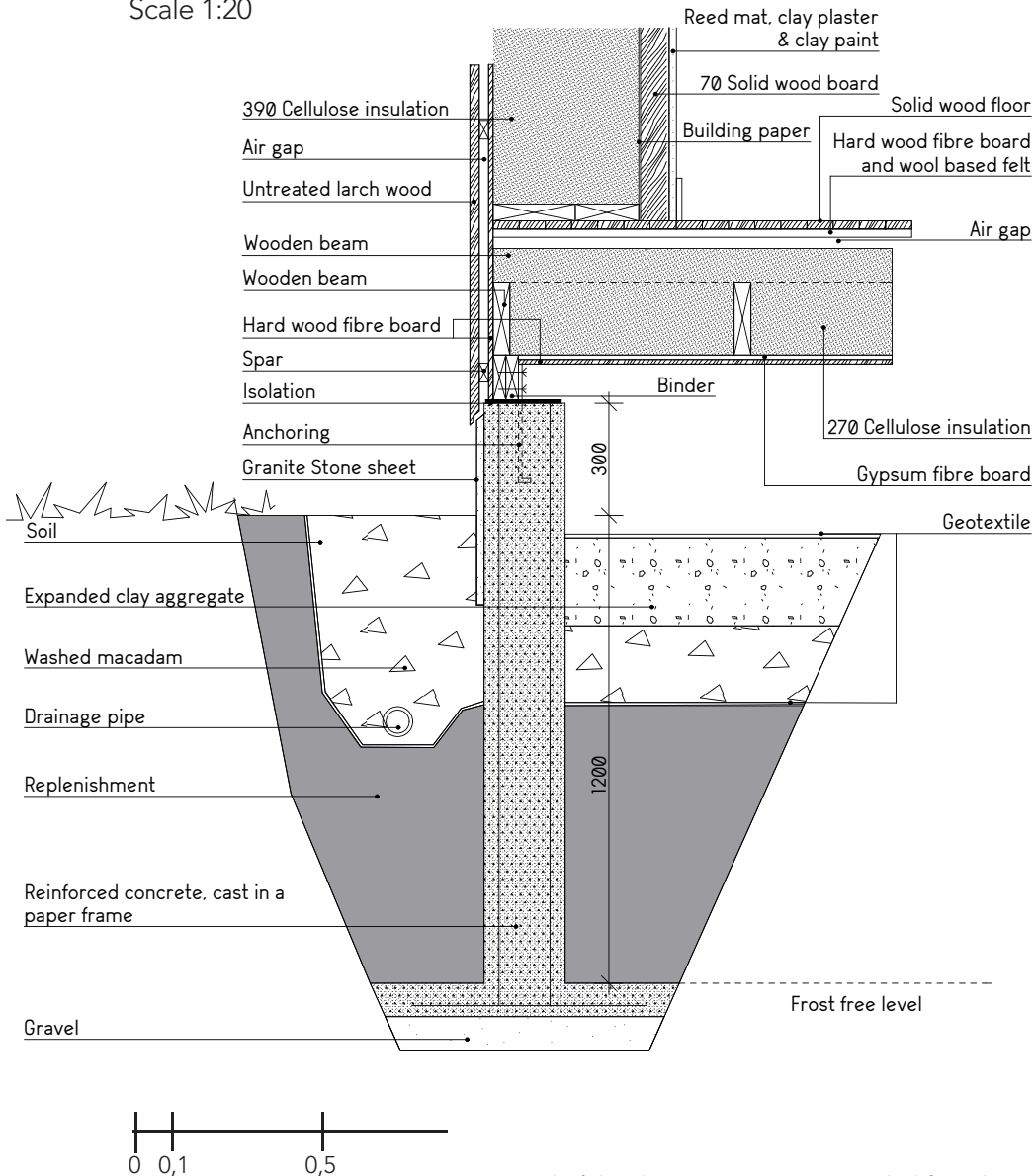
The slab method is also used when constructing a heated foundation. This foundation is constructed as a slab with one bottom layer and one floor layer with air cavity in between. This layer can be heated up by either floor heating or by leading exhaust air down to the foundation before directing it out from the building. (Sternberg and Lanne 1992)

A suspended foundation has a ventilated space underneath the construction. This way of constructing the foundation was common in the early days when the building was heated by a stove. The chimney of the stove went all the way through the foundation and down to the ground. This kept the space under the foundation warm and dry. Today, stove's are not commonly used to heat up buildings and this type of construction often gets problem with the ventilation and heating of the space which in many cases causes moisture damage and mould growth. (Sternberg and Lanne 1992)

Placing the building on plinths is a good method to avoid causing too much damage on the ground. The plinths can be cast in concrete or be constructed of wood placed on a concrete base cast on site in the ground (Sternberg and Lanne 1992). Plinth foundations are the safest choice from a moisture protection point of view as they result in the least ground contact and because the air can move freely underneath the building.

FOUNDATION - dry area

Scale 1:20



Detail of the design project's suspended foundation with a suggested composition of materials

The disadvantage with a plinth foundation is that it gives the building another surface from which the heat can escape the building which demands a thicker insulation layer (Bokalders and Block 2010).

The fourth alternative is to have a cellar, but the city detail plan does not allow the construction of it in this area.

In my design I chose to have a plinth foundation in the 'dry areas' where the wall construction is made of wood and a slab foundation in the 'wet areas' where the walls are built up by brickwork. I consider the plinth foundation as a better alternative and chose therefore to combine the two instead of cast concrete underneath the whole building. The garage will have the same type of slab construction as the 'wet areas' to allow for a flexible floor plan when a car is no longer needed.

How these foundation types will be attached and work together in terms of movement, insulation and moisture protection needs to be further examined by a building engineer. As well as the dimensions of the suggested materials shown in the detail drawings. I mainly made the drawings to present how the different materials relates to each other.

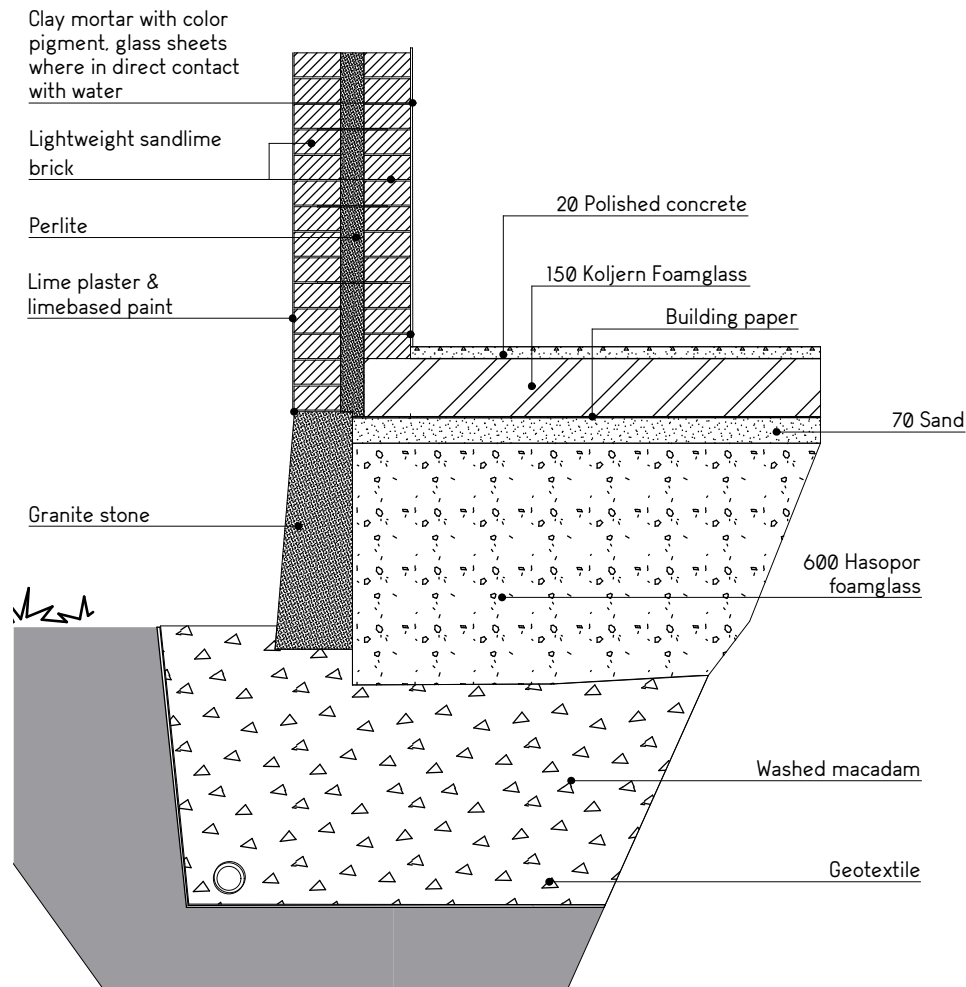
Suspended foundation

The dry areas with wooden walls have a foundation constructed of wooden beams. A hard wood fibre board shelters the foundation from the outside air. Above there is a second layer of gypsum fibre board. This board consist of gypsum paste and cellulose fibre from recycled paper. The gypsum fibre board is stronger than a gypsum board. It is both wind-proof, heat-retentive, fire-resistant, moisture-buffering and sound-absorbent (Bokalders and Block 2010). As insulation I chose loose cellulose fibre. The top material is made of solid wood screwed on top of a hard wood fibre board with wool based felt in between to reduce footfall. For an easy dismantling and reuse of the floor, screws are used instead of nails and glue.

The solid wood flooring is made of spruce, treated with a substance made of linseed oil. There are no chemicals added in the oil which makes it 100% organic. It has been used in centuries and can be mixed with different organic pigments to give a wide range of colours. Cold-pressed linseed oil is more resistance to mould growth, and other pollutants, than warm-pressed oil. The later one, in the other hand, extracts a larger amount of oil from the seeds and makes the oil darker. (Träguiden 2003)

FOUNDATION - wet area

Scale 1:20



Detail of the design project's slab construction with a suggested composition of materials

Slab foundation

Half of the building will be constructed by using brick walls to create a breathing structure to spaces with higher moisture content. In this area the foundation will be placed directly on the ground and have a concrete covered floor that can stand against water leakage and be used as shower flooring.

When composing the detail of this foundation type I used the building Villa Circuitus as a reference building. Villa Circuitus is a private villa built to cover the demands of a passive house. They used healthy, both traditional and new, materials when constructing the building components. The construction drawings with a list of all materials can be found on their website (<http://circuitus.se/projektbeskrivning/konstruktionsritningar/>).

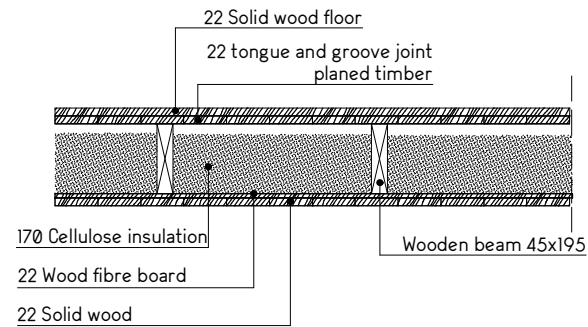
The ground cover for both foundations will be a primer layer of geotextile which separates the materials but are letting the water go through. Upon the textile there will be a layer of washed macadam which works as a drainage layer. The pebbles are big enough to let the water sip through while it at the same time stabilizes the ground.

The next material in the slab foundation is foam glass from a manufacture called Hasapor. Their foam glass is produced of 100% recycled glass from Swedish households. The foam glass is produced in pieces with a diameter of 1-6cm. It looks like crushed stone pieces but because of their air-filled pores, which it gets in the fermentation process, it is eight times lighter, has a very good insulating ability and is also very stable. The size of Hasapor foam glass also makes it a good drainage material which prevents the water to reach the slab construction from underneath. The material is very stable in steep constructions and I therefore used it outside of the walls that are partly underground. The thermal conductivity (lambda value) of the material is 0,102 W/mK. (hasapor.se 2017)

Above the Hasapor foam glass there is a layer of sand to create a flat and even surface before placing the foam glass boards from the manufacture called Koljern. The Foam glass in the boards are made by blowing air and pulverized coal into melted glass, creating a closed structure with small air bubbles. Producing the material demands a lot of energy but it has a very long lifespan and it works both as insulation and finished floor structure. It is not necessary to cast concrete upon it. The boards are waterproof, non porous, do not attract mould and do not burn. They are laid as blocks on the ground and can be dismantled and reused easily (Bokalders and Block 2010). The boards are prefabricated for the specific

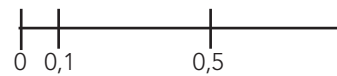
INTERMEDIATE FLOOR - attic

Scale 1:20



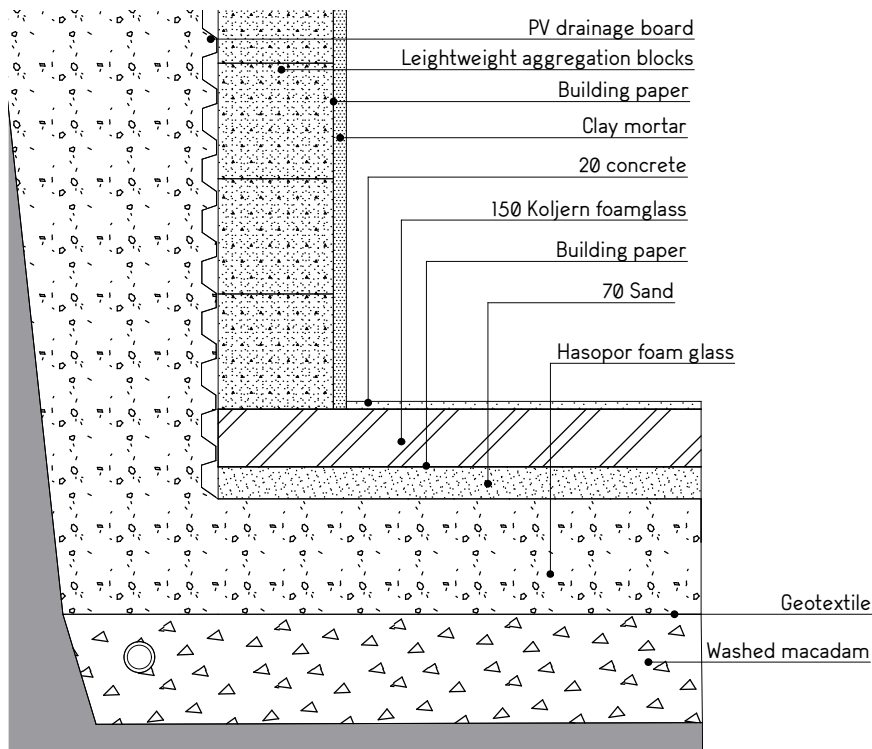
Detail of the design project's intermediate floor
with a suggested composition of materials

project and are easy to install (SP Sveriges Tekniska Forskningsinstitut 2016). On top of the boards are a thin layer of concrete to ensure water tightness in the wet areas of the building. Instead of using tiles, which demands less good materials such as waterproof membranes, cement mortar and silicone I chose to leave the concrete as it is and use polish to bind the dust and get an aesthetically pleasing surface.

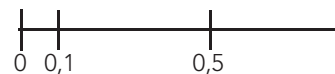


FOUNDATION - garage

Scale 1:20



Detail of the design project's slab construction below ground level with a suggested composition of materials



Wall

Wooden facade

I have decided to combine two different type of walls, one is constructed by brickwork and the other one of wood. This is because of their different abilities to absorb moisture and create a good indoor climate. In damp areas such as in the bathrooms and the laundry room, the walls need to be able to absorb and regulate the moisture content in the air rather than be repellent and risk to develop moisture damage in the insulation layer. In dry areas a wall constructed by wood is better in terms of energy savings in the production of the material. Since both brick and wood should be placed at least 30cm above ground level to avoid moisture damage, granite stone will cover the areas that are in direct contact with the ground.

To choose wood as a building material does not necessarily make the building healthy for the environment. To make the wood sustain longer it is important to choose right surface treatment and to know which part of the tree is best to use for what purpose.

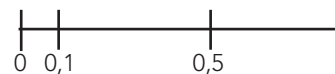
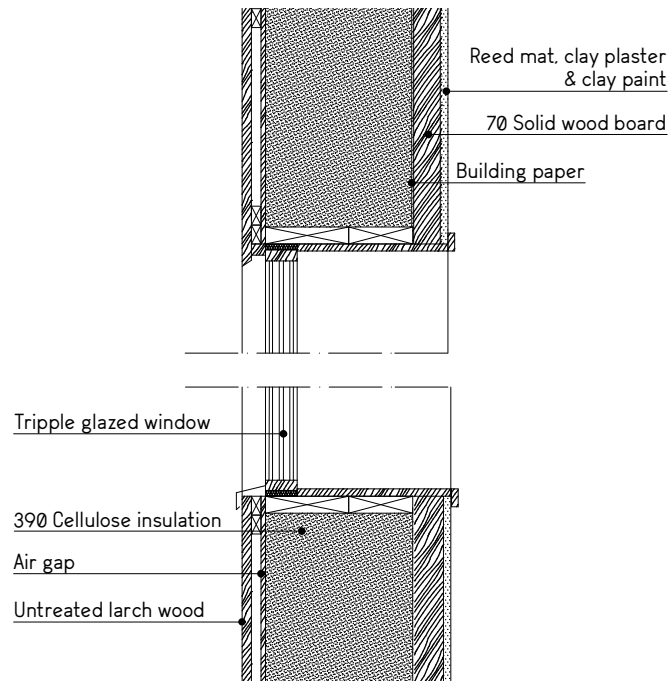
When choosing wood as facade material it is best to place the wood vertical and seal the end-grain surface so that the water can run off easily. All wood that are placed outside should have a high percentage of heart wood since it has a lower ability to absorb water. (Sandberg et al. 2011)

To treat the surface is an effective way to make the wood sustain longer, be resistant to moisture and rot. However, not all surface treatments are good for the nature when it is time for the wood to be recycled. Wood works almost always as energy fuel but some surface treatments contaminates the ash which then classifies as dangerous and cannot be returned to the nature. The use of surface treatment cannot be fully avoided, at least not when it comes to the construction of the foundation but it can be avoided in the facade.

Untreated wood bleaches in the sun over time and develops a grey tone. The surface erodes and a thickness difference of 5mm can be expected after 50years. The facade changes over time differently in south, west, east and north depending on the sun, wind and rain. The surface of the wood will never be monotone because every board will react individually. Since the size will differ over time and it is important to think about how the boards are positioned and attached. A good rule is to keep the boards under 160mm wide (Hansson 1999)

EXTERIOR WALL - Dry area

Scale 1:20



Detail of the design project's wooden walls with a suggested composition of materials

All wood can be left untreated but a few of them handle it better than the rest.

Except from different woods' natural stability it is important to consider the woods hygroscopic characteristics when deciding which wood to use for what purpose. Amongst the Swedish wood types, oak is the one with highest resistance, when it is placed in direct contact with the ground (15-20years). The second best is larch (15years) and pine and spruce is tied in the third place with 10 years. (Bergkvist and Fröbel 2013)

Due to economical reasons oak is mostly used indoors for furnishing and larch is a common material to choose for an untreated facade. The closest sawmill producing larch wood lays only 30km away from the building site in a village called Knäred and the company is called Svenshults såg.

The most common larch wood used in buildings are Siberian Larch *Larix sibirica*. But the Siberian larch has a hard time to compete with the more common hybrid larch *Larix eurolepis* which is more common in the Swedish south. Siberian is considered better because of denser and more rot resistant wood, it grows straighter and can survive the autumn frost better. Larch overall is considered good for the nature because it provides variation and light to an otherwise spruce and pine dominated forest. Larch trees are harvested at an age of 55 years and sometimes even after 70 years if the producer wishes to have a heavier wood with high quality. Larch is better left untreated than many other trees because of its high amount of heart wood and its high resistant against rot growth. (Arvidsson 2006)

The heart wood have a strong red-brown color before it turns grey when left untreated and exposed for weather and strong sunshine.

Stone facade

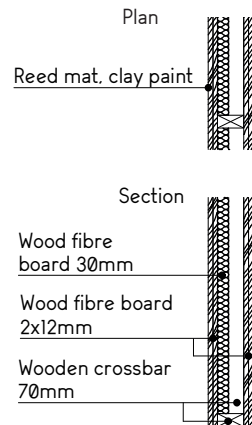
The building is partly placed under the ground level because of isolating reasons and adaptation to the existing landscape. Since wood is recommended to be situated at least 30cm above ground level another material is needed to cover areas in direct contact with the ground. For this purpose, I have chosen stone.

Stone is a natural material with a long lifespan. It only needs to be carved, cut into pieces and transported to the building site. It does not need to be maintained or replaced over time. The closer the production site is, the better.

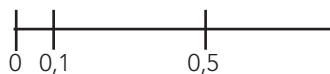
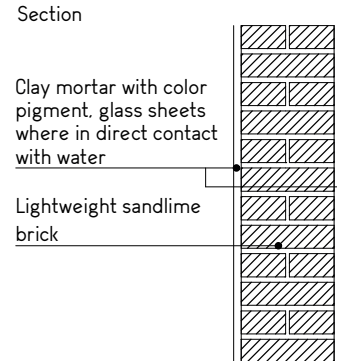
Stone is an expensive material to buy but the lifetime is endless when using it in the right way. The cost can be divided into two parts, the

INTERIOR WALL - Dry area

Scale 1:20



INTERIOR WALL - Moist area



Detail of the design project's wooden walls with a suggested composition of materials

investment cost and the maintenance cost. The investment cost is the larger part. Mounting of the stone is more expensive than the material itself and it is therefore worth to choose a more expensive stone with better quality. The maintenance cost is low if the stone is placed in the right place, only simpler methods are needed to clean the surface.

The Swedish bedrock consists of rock types that varies in age from three billion to some tenth million years. Rock types over 900 million year dominates. The different rock types that can be found in Sweden are marble, limestone, schist, sandstone, soap stone and granite. The stones have different properties and they cannot all be treated in the same way. Some stones are more fragile than others. Thin plates of Carrara marble can start bending over time, also thin plates of other stone types can bend if they are exposed to moisture for a longer period. The porous stones such as sandstone and limestone can be damaged by frost wedging if exposed to a lot of water. Almost all stones develop a patina over time. Patina is defined as a non harmful change of surface regarding colour which gives the stone an impression of its age. Limestone and bright marble gets a yellow tone, if exposed outside, during a longer period of time. Sandstone goes brown or black, granite goes darker and black shiffer gets a grey surface. This change happens because of oxidizing minerals, pollution and changes to the mineral on the surface. (Riksantikvarieämbetet 2013)

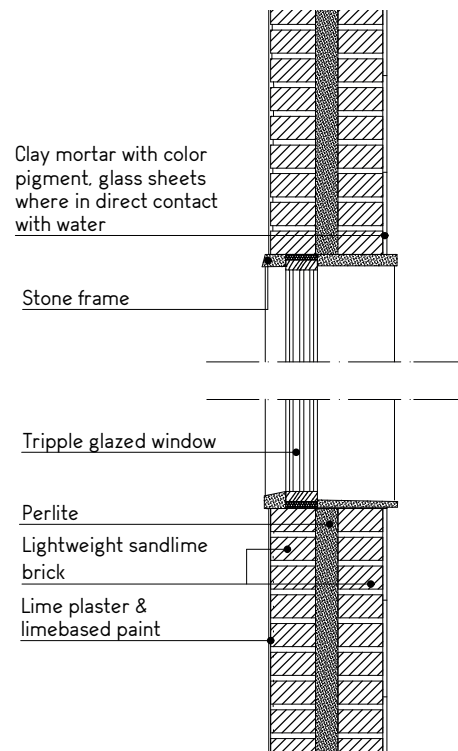
When evaluating the environmental footprint of stone it is important to take into consideration the material's long lifetime compared to other materials. It is the breaking, processing and transportation that stands for the environmental impact. The removal of the stone itself also harms the nature and landscape where it is situated. Stone is a natural material but it is not renewable in a realistic future since it takes many thousands of years for it to be created. In many cases stone ends up in landfills after demolition because of the extensive work of cleaning the blocks from old joint mortar. Other reasons are also the cost of storing and transporting the used stone. (Riksantikvarieämbetet 2013)

I have decided to use granite which is often used in paving, stone walls and as plinths.

Stone cladding is installed with stainless steel metal anchors so that it can be ventilated on the inner side.

EXTERIOR WALL - Moist area

Scale 1:20



0 0,1 0,5 — Detail of the design project's brick walls with a suggested composition of materials

Brick facade

The lower parts of the building will be constructed with brick walls. Brick and clay are permeable materials which helps regulating the air's moisture level and it fits therefore well in bathroom walls and other areas with high relative humidity. Bricks are made from clay which has been dried, preheated and burned for about 3 hours. The higher temperature the more fire proof the brick gets. Because of energy reasons it is better to choose bricks which have been burned at as low temperature as possible. By adding sawdust the brick will get improved insulation. Sawdust will burn off and leave small air cavities in the brick.

Bricks are maintenance free and can be treated with a clay surface painted with a lime colour to change its appearance. (Bokalders and Block 2010) Bricks can be reused if it is dismantled with care, it's easier if clay mortar has been used in the construction of it. The downside with bricks is that the binding agent for outside walls is cement and the insulating properties are so low that extra insulation is needed.

Bricks can also be made of quicklime and sand, which are then mixed with water and pressed into brick-shaped blocks. The brick is then hardened at a temperature of 200-300 degree Celsius for about 3-4 hours, a process which demands less energy than burning bricks made of clay. The moisture-buffering capacity is only a third of bricks but can be improved with the use of plaster. By adding up to 90% expanded clay you get lightweight sand lime bricks which have almost the same properties as expanded clay blocks. The differences between the two are that the binding agent for lightweight sand lime blocks are lime and not cement which is more environmentally friendly. The thermal conductivity for the material is 0,13W/mK. while for brick it is 0,47W/mK (Bokalders and Block 2010). I therefore choose to have lightweight sand lime brick with an exterior cladding of lime plaster.

The material in the walls, partly placed underground, will be built up by lightweight concrete. This material is made of finely ground sandstone/ quartz sand, lime, cement, natural gypsum, water and a little sand. Aluminium powder is added to make the mixture expand and create air bubbles. Lightweight concrete has average heat accumulation properties and good compressive strength. The life of the material depends on the quality of the binding agent which is cement. (Bokalders and Block 2010)

Insulation

The main key property of a thermal building insulation material is the thermal conductivity value. Thermal conductivity is a measurement of a material's ability to transfer heat. Therefore, the lower thermal conductivity value the higher insulation properties. The unit for thermal conductivity is W/mK and it is calculated by taking the thickness of a material and divide it by its thermal resistance/multiply the thickness with the material's U-value. This concludes that it is possible to get a thin building envelope with high insulation properties if a material has a high thermal conductivity. (Jelle 2011)

Thermal conductivity of potential insulation materials, rated with the lowest value first:

Cotton Wool insulation	0.029
Sheep wool	0.039
Fiber glass	0.04
Glass, wool Insulation	0.04
Cellulose fibre	0,04
Cork board	0.043
Fibre insulating board	0.0484
Sawdust	0.08
Charcoal	0.084
Straw slab insulation, compressed	0.09
Plywood	0.13
Wood wool, slab	0.1 - 0.15
Timber, birch	0.14
Timber, pitch pine	0.14
Brick, insulating	0.15
Timber, ash	0.16
Hard woods (oak, maple..)	0.16
Wood, oak	0.17
Timber, oak	0.17
Concrete, lightweight	0.1 - 0.3
Clay, dry to moist	0.15 - 1.8
Plaster light	0.2
Brick, fire	0.47
Concrete, medium	0.4 - 0.7
Brickwork, common (Building Brick)	0.6 -1.0

Glass	1.05
Concrete, dense	1.0 - 1.8
Brick dense	1.31
Brickwork, dense	1.6
Concrete, stone	1.7
Sandstone	1.7

Source: "Thermal Conductivity Of Common Materials And Gases"

According to the list "Thermal Conductivity Of Common Materials And Gases" received at the website Engineeringtoolbox.com the materials with lowest thermal conductivity is cotton wool, sheep wool, fibreglass, glass wool, cellulose fibre, cork board, fibre insulating board and sawdust. Fibreglass and glass wool are not renewable materials and will therefore not be considered in this design.

Besides having a high thermal conductivity other aspects have to be considered when choosing a material such as environmental impacts from transports, cultivation and production methods. A material need to be renewable, reusable and preferably produced close to the building site to avoid long transportation routes.

Cotton wool is a renewable material but the production of 1kg cotton needs more than 20,000 litres of water and 73% of all global cotton harvest comes from irrigated land (Brandt 2014). The transportation of cotton from production to use is long and energy intensive and boric acid must be added as flame retardant (Bokalders and Block 2010). Sheep wool is a good option due to its low impact on the environment and natural production. It is cheap but if untreated it is highly possible that it will be inhabited by worms. Today there is no better option to prevent this than adding chemicals (Lundström 2006).

Fibre glass and glass wool insulation have good isolation properties but they are not renewable or reusable. Cork board is another material with low thermal conductivity but the fact that the cork-tree only grows around the Mediterranean Sea makes it a non-sustainable material to use in the north.

Cellulose fibre is a good insulation material which has a thermal conductivity of 0,04 W/mK. The insulation is made of recycled newspapers or newly produced cellulose. It can be delivered as boards, loose fill or as packing strips. Chemicals are added to make the material less flammable and can account for up to 14-25 per cent of the weight of the material. If installed correctly the material is highly airtight, which counteracts

convection in the construction. The production of new cellulose is energy intensive but creating it from recycled paper is very energy efficient. (Bokalders and Block 2010)

The next material on the list is wood fibre insulating board. This material is a good candidate for the northern climate. The closest factory lies 165km away from the building site and the board is made out of wood from the area around the factory. The company's name is Hunton and they have their head office in Norway. According to their declaration of performance their wood fibre insulation board have a thermal conductivity of 0,038W/mK and a density of 50kg/m³. The resistance value (R) is 1,18 (45mm thick), 1,84 (70mm), 2,50 (95mm) (Hunton.se 2017). The board is produced by 86% wooden fibre, 6% bi-component fibres which is a combination of polyester/polyethylene used to bond non-woven materials and 8% ammonium phosphate.

According to a study performed by Geving et al. the wood fibre insulation performed slightly better or similar to the glass fibre insulation during the summer and slightly worse or similar during the winter. While the glass fibre had a faster response to drying and wetting the wood fibre had a slower and more retarded response to changes (Geving, Lunde and Holme 2015).

To improve the insulation of the double brick wall, perlite will be added in the cavity in between the walls. Perlite have a thermal conductivity of 0,04-0,05W/mK. It is produced by heating up glass with volcanic origin to one thousand degrees Celsius. The glass will then expand to a volume 15-20 times larger than the original size. The raw material can be found in Greece, Turkey, Iceland and Hungary. It does not burn or react chemically with other materials. It does not bind water and is therefore suitable for a brick wall meant to be exposed for moisture and be able to breathe. (Bokalders and Block 2010)

Binding agent

It's not only the material itself that have an effect on the environment but also the binding agent, in this case the binding agent that keeps the stone blocks together. It is not only the binding agents effect on the environment that should be taken into consideration but also how it affects the demolition of the building. A binding agent that is ecological such as clay together with stone ensures that the material can be reused or used as filling without spreading any dangerous substances to the ground.

Other binding agents used in the industry are asphalt, cement, gypsum and lime.

Asphalt is never good because it is a bi-product from the refining of oil. It is used to prevent moisture penetration and if not distilled properly, contains the unhealthy component polycyclic aromatic hydrocarbons. Cement contains of quicklime, silicic acid, feldspar-bearing clay, calcium sulphate, blast furnace slag, fly ash, oil shale, bentonite etc. The production of cement is very energy intense and generates harmful greenhouse gases. To ensure a long lifespan and control the hardening process chemical additives are used. Gypsum is especially suitable for indoor use. It is a good sound insulator and has good heat storage and fire resistant properties. Lime has many valuable properties, it both absorbs, and releases moisture and it has disinfecting qualities. However, the production of it is very energy demanding. The limestone needs to be heated up to 900 degrees Celsius, together with added water it combines carbon dioxide in the air and turns back to solid limestone. (Bokalders and Block 2010)

Clay can be found almost everywhere in the ground. When referring to clay, it is the mixture of clay and sand which is used in walls, as plaster and mortar. To increase the clay's properties other materials can be used such as straw and sawdust to increase the insulation properties and branches or animal hair to increase its strength. Clay construction is a demanding and labour intensive work and it need to be done during the summer so that it can dry out well. Clay has good properties as a moisture buffer and ensures a stable and comfortable humidity condition. Clay mortar is easy to dismantle because of its softness and weakness. It can also increase and shrink without cracking because of the same reason. (Bokalders and Block 2010)

Interior cladding

A common material to use in construction of the inner walls is gypsum. There are three types of gypsum; natural gypsum that is mined, power-station gypsum (REA) that have similar properties as the natural but is processed by solid waste from industrial desulphurization of flue gases and the last one is phosphogypsum. Phosphogypsum can contain naturally occurring radioactive materials and dangerous heavy metals and should therefore be checked before use in construction. Natural gypsum is made from gypsum rock. It is a rock composed of calcium sulphate and commercial quantities are found in Germany, Canada, the US and Eng-

land. It is burned at 200°C to force the water out of the gypsum and when mixed with water again it hardens, and the gypsum rock is reconstituted. (Bokalders and Block 2010)

I will not use gypsum in my design. Instead I will cover the interior wall surfaces with pigmented clay plaster. Clay ensures a good indoor climate because of its moisture buffering properties. It is also fire-resistant and accumulates heat. The Finnish company Saviukumaja is both manufacturing lime- and clay plaster. It is 100% natural and produced only by using solar energy. The clay plaster can be given in a dark-red, red, green, blue or grey colour. To attach the clay plaster to the solid wood surface a thin reed mat is used. The clay builds up to 4mm on the wall. (Saviukumaja)

Clay plaster cannot be used in areas exposed to a lot of water so in these places - next to the shower, bathtub or above the tap in the kitchen - glass sheets will be used to protect the surface. I want to avoid ceramic tiles because of the extensive use of energy needed to produce them. Tiles are often shipped from abroad and their heavy weight does not make the shipping any better. They are mounted in cement mortar and because of the joints there needs to be a waterproof layer underneath, unless the mortar is not made of minerals and/or tolerate moisture.

Roof

Roofs are as important, if not the most important, as the rest of the envelope; around 60% of the thermal energy leakage occurs through the roofs (Suresh, Madala, and Boehm 2011). Heat travels upwards and the building components are especially crucial in areas where hot and frigid air meets. Thick insulation can result in moisture damage due to lack of ventilation of the hot air. The hot air, containing high percentage of moisture, gets stuck in the ventilation, freezes in wintertime and starts melting in spring which result in ceilings with moisture damages.

Common materials when it comes to roof cladding is clay tiles, metals, stone and wood. Metals should be used sparsely because of its huge negative impact on the environment. It creates dangerous waste and demands a great amount of energy in the production. It is important to reuse metals, especially aluminium which takes 95% more energy to produce than reuse. If metal is needed the best ones to use, from an environmental perspective is steel, iron and reused aluminium. Iron is the least energy demanding material but if used outside it needs to be protected by a surface coating to avoid corrosion. The three most toxic metals are copper, zinc and chromium. They are all listed in the Swedish Chemicals Agency PRIO database of priority risk-reduction substances. (Bokalders and Block 2010)

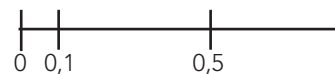
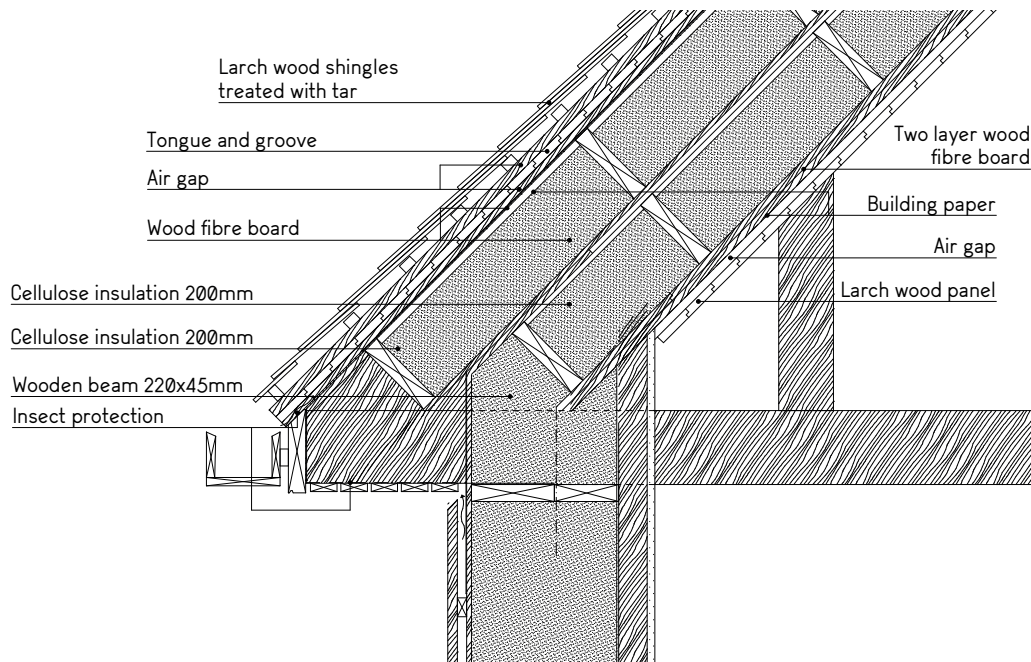
Another roof solution is the so called sedum roof. This is a construction where vegetation is placed on the roof. If the vegetation should stay the angle of the roof needs to be less than 45 degree.

Larch wood is as mentioned a very durable material when it is left untreated. This makes it not just suitable as a facade material but also as roof cladding. For this and because of aesthetic reasons I chose to have larch wood as roof material as well.

The wooden roof can be made in two different ways. One way is to overlap wooden boards (in Swedish it is called "Faltak") and the other way is to shape the wood into shingles. Faltak is a Swedish traditional way of constructing wooden roof in residential buildings while shingle roofs are more common in churches. According to Svenskt trä a wooden roof have a lifetime of approximately 30 year if it is constructed in treated pine wood and a bit less if untreated pine or larch wood is used (Brandt 2014). What is positive about this is that the roof can be changed successive because it is easy to change only the specific board that needs to be

PITCHED ROOF

Scale 1:20



Detail of the design project's roof structure
with a suggested composition of materials

replaced. It is important to keep the roof clean from branches and leaves to make it sustain for a longer time.

A faltak have a weight of around 0,75kN/m² including construction, ceiling and sealing layer. The thickness of the boards should be at least 22mm and the most common dimension is 22x145mm. The boards need to be wider then 70mm so they can fit a drainage channel. The best way to attach them is to nail them together by hand. The nails should be made of acid-proof stainless steel to avoid stain from rust. For the underlying construction it is recommended by Svenskt trä to use spruce because of its properties regarding moisture absorption. (Träguiden 2013)

A shingle roof can be constructed by either thick or thin shingles. The weight of the roof is the same as for the faltak, 0,75kN/m² including the bearing construction and the ceiling. Shingles made of spruce or pine needs a thickness of >25mm to meet the European fire recommendations. To impregnate the shingles and protect them from moisture and sun rays tar can be used. Shingles should be dipped in hot wood tar before mounting and the finished roof should be treated with it before the first summer. After that the roof should be treated every fifth year on the south side and tenth on the north. If a shingle roof is treated like this on a regular basis the roof can easily stand over 100 year. Which is a lot compared to impregnated wood shingles without tar that only holds for around 30 years.

If thinner shingles are used (>5mm) they can also be treated with tar but also be left untreated. If the shingles are handmade and carefully crafted they can hold untreated for 50-70years. Shingles made in an industrial saw only lasts for less than 20 years and fits better as facade material. (Träguiden 2013)

Wood tar is a traditional substance, since the middle ages it has been used to preserve wood for boats, jetties, docks and shingle roofs. It is a suitable alternative to pressure impregnation and it protects the wood from rotting. The tar is glossy in the beginning but darkens with time. It is important to choose natural wood tar and not tar made from coal which has a greater health risk. To give the tar a water repellent and dry surface the substance is mixed up with linseed oil and gum turpentine. This is a traditional recipe used in the impregnation of wooden boats. (Bokalders and Block 2010)

Ventilation

There are different opinions concerning the ventilation needed to stay healthy. Some people believe that a lot of ventilation can prevent allergy while others claims the opposite. A moisture rate between 40-60% is needed to stay healthy and heavy ventilation during wintertime reduce this number significantly.

When there are no mechanical driven fans that transports the air, it is called natural ventilation. It can be a closed system where the ventilation needs to be controlled by hand by opening windows for short amount of time during the day. Another way to get the air moving is by using the principle of the chimney effect and to take advantage of the fact that warm air rises. By constructing air chimneys the hot air rises and cold air sucks into the building through ventilation holes close to the windows. Natural ventilation is good in the sense that it does not need any electricity to work. The disadvantage with the method is that it is hard to get a steady flow and get heat recovery from the exhaust air. There need to be a relative big temperature difference between the indoor and outdoor temperature, which is seldom the case, during summertime. In wintertime the difference can be too big and create a heavy draught in the building and a storm can create undertow in the system. This can be avoided by installing ventilators, driven by a thermostat, that narrows the opening during wintertime and widens it during the summer. Another option is to place a small fan that will help driving the warm air out during the summer. Natural ventilation requires some effort from the people living in the building. (Sternberg and Lanne 1992)

Mechanical ventilation can work for both supply air and exhaust air or for only exhaust air. Exhaust air ventilation and natural ventilation both works by creating a low air pressure and in that way naturally pull in fresh frigid air. The combined supply air and exhaust air ventilation is called a balanced system. The combined ventilation system is often connected to an air heating system and the exhaust air ventilation can have a heat recovery system that is connected to a heat pump.

Mechanical exhaust air ventilation works like the natural system but since it has a mechanical driven fan the air flow becomes steadier. Air intakes should be placed in bedrooms, the living room and the outlets in the kitchen and bathrooms.

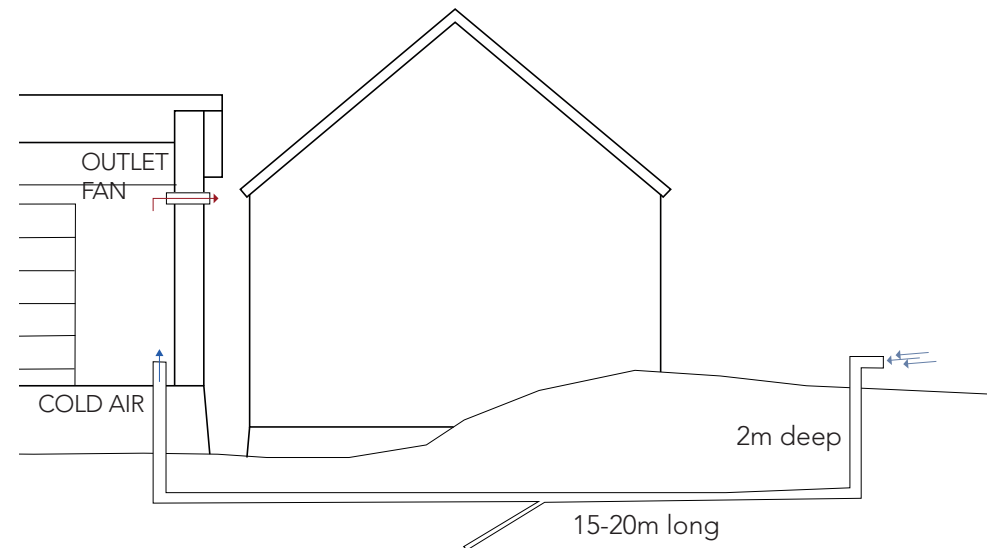
A combined ventilation of both supply air and exhaust air demands a

good control over the pressure balance. An excess of pressure inside can lead to moisture damage inside the walls. They also demand a lot of energy and can be noisy.

In this project, the exhaust air ventilation is used together with an exhaust air heat pump to be able to recover as much heat as possible from the otherwise lost exhaust air. The air is sucked out using fans in the kitchen area, above the showers, laundry room and in the sauna. The inlets are part of the windows and they can be manually open and closed depending on the users preferred indoor temperature.

The storage area which is reached from the entrance is meant to be cold and used as a larder where it is possible to store food for example. To keep the room chilled, cold air will be taken through a pipe buried in the ground

VENTILATION & COOLING OF STORAGE SPACE



Heating

Heat pump

A heat pump uses the heat that exist naturally and for free, and converts it into higher temperatures through a compressor. The heat can be extracted from the air, ground or water. A ground source heat pump is considered better because the heat in the ground is somewhat similar during the entire year while the air temperature changes more randomly and forces the heat pump to work harder during the cold months when the need for heating is at the highest. A heat-pump is powered by electricity but the heating degree efficiency of the used electricity is up to 300% which makes it more efficient than for example using radiators powered with electricity. For the best efficiency it is recommended to use water-borne floor heating instead of radiators because heat pumps prefer to work towards the lower temperatures. The highest economic efficiency will be achieved by having a feeding temperature of 35°C.

A heat pump can be directly connected to the heating system or through an accumulator tank, which is needed if also, for example, solar collectors are in use. (Zäll 2012)

There are three types of heat pumps: ground, air to water and air to air. The heating coil for a ground source heat-pump can be placed in the bedrock, in a lake or one meter under the ground in the garden. The air to water heat-pump takes the heat from the outside air and uses it to heat up the household's water supply. The air to air heat-pump takes air from the outside and heats the inside air directly. There is also a fourth one which is called exhaust air heat-pump. This one is reusing the heat in the air which would otherwise go lost in the exhaust air ventilation. (Birgersson 2016)

A ground source heat-pump is expensive to install and is therefore more suitable in bigger buildings with several households sharing the expenses of it. The air to air heat-pump does not provide hot water, only heated air. Both the air to water- and exhaust air heat-pump provides hot water and they are both most suitable for water borne floor heating system because of their lower heating capacity. The exhaust air heat-pump is a good sustainable alternative because it reuses the heat that is naturally provided from people and machines. A mechanical ventilation system is needed to steer the exhaust air through the heat-pump and then let the,

now cold, air go out of the building. (Polarpump.se 2017)

Even though a heat pump works best together with floor heating I chose to only use floor heating for the concrete casted floors and instead use cast iron radiators in the living room. This is because there is a significant risk of placing water borne floor heating pipes in a wooden foundation. If the system would fail the reparation work would be very expensive and complicated.

Waterborne floor heat can also consume up to 30% more energy than radiators because of bigger heat losses and it is slow in adjusting to changes in temperature. (Bokalders and Block 2010)

A heat pump is dimensioned to work only between the average high and low temperatures, in this case between 4,3-10,6 °C. If the temperature would drop lower than that an additive heat source is needed. What is not better than a fire-burning stove during cold winter nights?

Fire-burning stove

To install a stove in a building is an effortless way to get extra heat in chilly days, A stove alone can sometimes be the only alternative to a passive heated building with a heat exchange ventilation system. A stove can be constructed in different ways and provide different outcomes.

A tile stove is a heavy construction of materials with high thermal conductivity such as bricks, concrete blocks or stone. The heat from the fireplace can continue radiate from the material up to one day after the fire is put out. This kind of heavy stove are sometimes covered by tiles but can also have a natural appearance of the construction material or be covered in plaster. If this kind of stove is placed nearby a southern window it works very well as a heat storage for the sun's heating radiation.

Another version of a stove is the one made of cast-iron or steatite, which where common to use for cooking before the electric stove came.

The third version is the modern ones made of steel sheets. They are light weighted and can be placed without having to strengthen the foundation.

I have placed a heavy tile stove in my design, built by bricks with clay as binding agent so it will be easy to dismantle. The construction is big to allow space for both wood storage and a holocaust system. A stove does not only radiate hot air but can also be combined with other technologies to maximize the use of heat energy it produces. One option is to connect a fan to it that will really spread out the hot air. Another way is to create a holocaust system. This system heats up chilly water by connecting

the accumulator tank with a water storage behind the back wall of the fireplace. (Sternberg and Lanne 1992)

Solar collector

Gaining extra heat can be done by placing solar collectors on a south facing roof and connect them with the accumulator tank as well. Solar collectors can not cover the buildings heating demand by itself but it is a good sustainable compliment to a heat pump or pellet boiler. With the right amount of collectors the system alone can provide the building with hot water and heating during the whole summer. The collectors should be placed with a 30 degree angle directly towards south to give the highest efficiency. The optimal degree for a whole year use would be 38 degree but since they are more efficient during the summer the installation will be optimized for that time span. (Sternberg and Lanne 1992)

There are two types of collectors where one is flat and can be integrated with the roof and leads heat through a copper string. The other one is made with vacuum pipes which have a higher energy exchange and it also works better than the flat when it is positioned in less favourable directions.

If the solar panels will be used only for hot water supply 5 square meter is enough for one single family home. If it is to be used for both heating and hot water 10-15 square meter is needed. This will provide one third of the house's total heating and hot water demand during one year (Bokalders and Block 2010).

Solar collectors need an accumulation tank to store and distribute the heat to the radiators or floor heating system.

A storage tank usually has three levels. The coldest water is in the bottom and it is on this level water from the solar collectors is transferred. In the middle layer the water is preheated and water from a water-jacketed wood burning stove is connected to this layer. The hottest water is in the top and it is ready to be distributed as tap water or to the radiators.

There are two other good options that I did not use in the design. These are the solar wall and the pellet burning stove. The solar wall was dismissed since it's not proven to give any significant effect in small areas. The pellet boiler was dismissed in favour for the heat pump since heat pumps are more favourable if run on renewable electricity.

In a dissertation called "Uppvärmning av fastigheter utanför fjärrvärmenätet" the author Christian Zäll (2012) compares the different alter-

natives; heat pump and pellets in different kind of house types. He compares the alternatives through taking into consideration their cause of environmental impact and economical properties. According to his report burning with pellets have a lower efficiency rate than a heat pump and is therefore more expensive. In the other end burning with pellets have a three times lower impact on the amount of released greenhouse gas than a heat pump has. In the report the electricity used for the heat pump is considered to be from a grid with mixed sources of the produced energy and is therefore not 100% renewable. However if the electricity came from sustainable source one can discuss if they are equivalent in their green house gas emissions. Also according to the report the maintenance cost for a heat pump is minimal, approximately 5000 Swedish crones per year - ca 500euro, while the cost for a pellets burner is closer to 25 000 Swedish crones - ca 2500 euro.

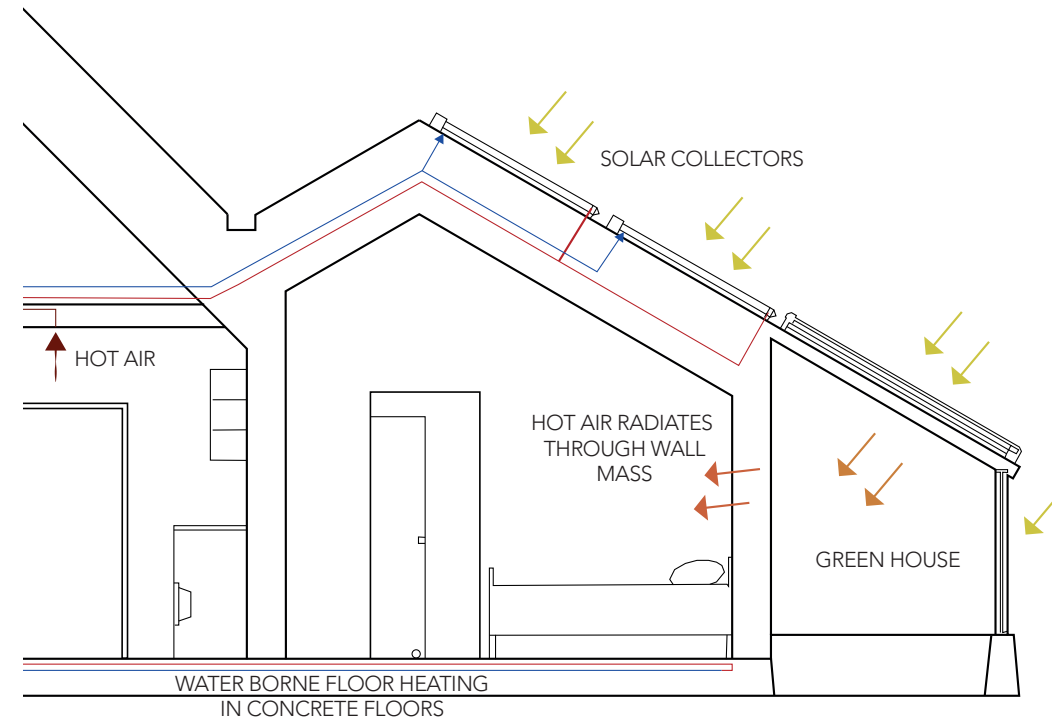
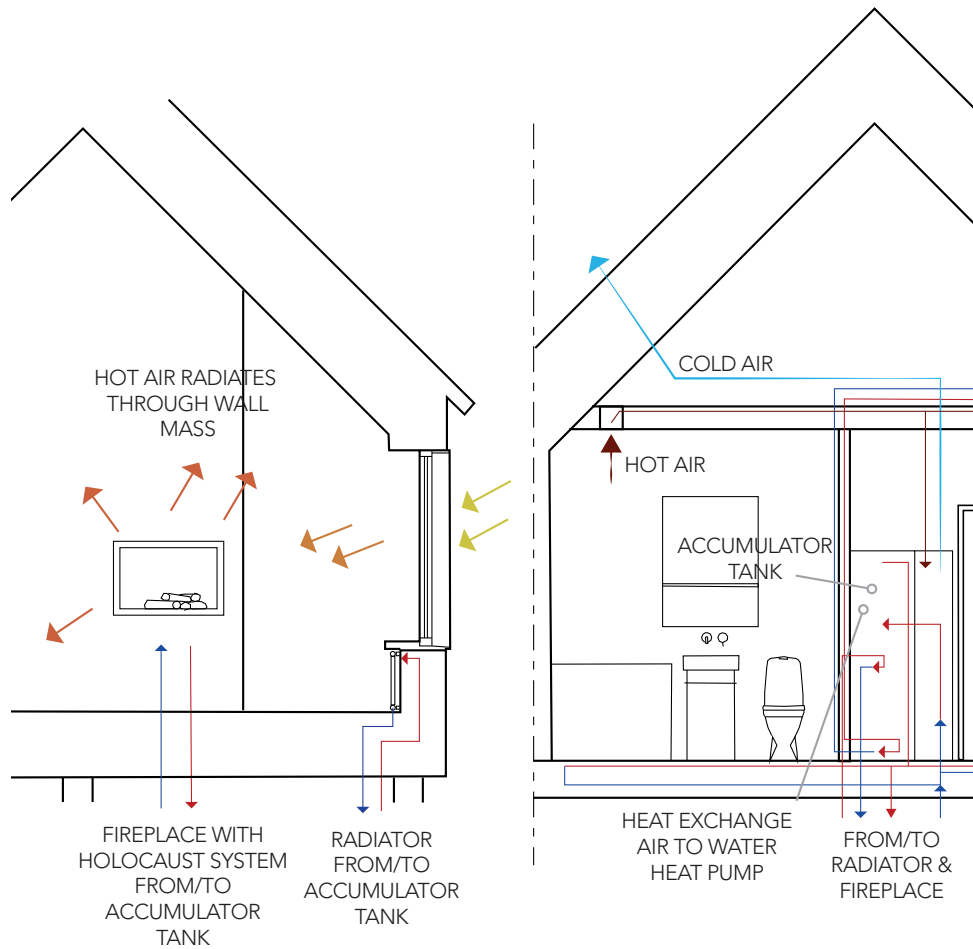
This table shows electricity, oil and pellets impact on the environment specified in amount of kWh per bought energy. Data representing oil is for Norwegian natural gas and the rest is for Swedish average electricity.

	Electricity	Oil	Pellets
Increased greenhouse effect (mg CO ₂ -ekv./kWh)	365 000	292 000	18 800
Acidification (mmol H ⁺ /kWh)	2,7	12	17
Ambient ozone (mg NO _x /kWh)	54	340	520
Ambient ozone (mg C ₂ H ₂ -ekv./kWh)	6,8	31	1700
Over-fertilization (mg O ₂ -ekv./kWh)	340	2000	3300
Particles (mg/kWh)	9	5,5	13

Source: Zäll 2012

HEATING DIAGRAM

This diagram presents the final building design's heating sources and how they are combined



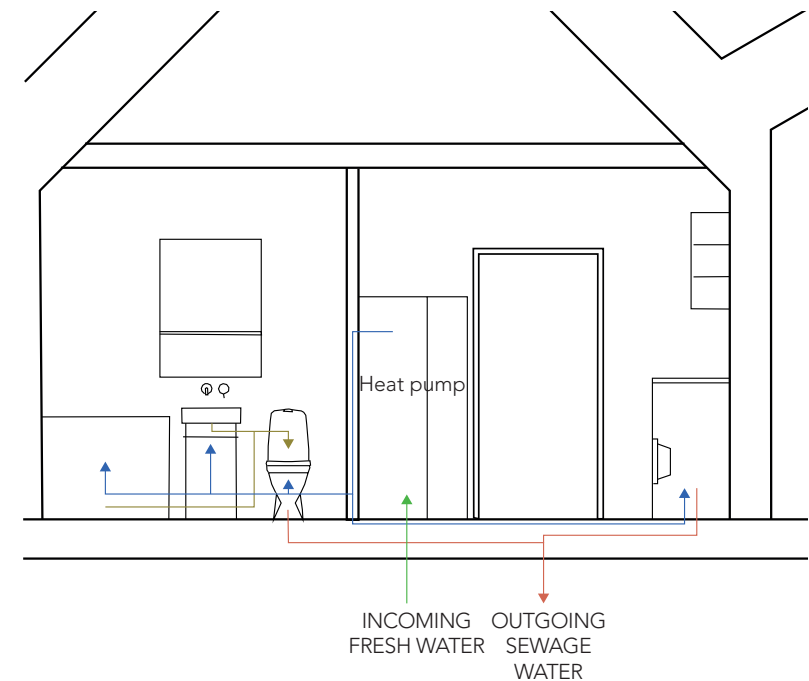
Water

The use of water is something that we should take seriously. We cannot survive without it, we need it in order stay hydrated but also to clean ourselves and maintain our personal hygiene. In the Nordic countries we are good at keeping our freshwater clean. We use the same clean drinking water in kitchen taps as we do in showers and even toilets. When the water has been disposed it goes directly out of the building. Clean tap water is mixed with soap water from the shower and washing machines and sewage water from the toilet.

The easiest thing to do to save water, is to choose taps, shower heads and products which uses the water sparsely. A second option can be to connect different water appliances in the building. Water from the sink, shower or washing machine can be connected to a toilet. The used water (called grey water) will fill up the cistern and be used for flushing. In this way the water can be used more than once. It is important to separate grey water from black water. Black water is the water that should not be used twice such as toilet water and water from the kitchen sink and dishwasher because it may contain harmful substances.

Another way to save a lot of water is to install a dry toilet. The dry toilet separates urine and faeces and is connected to a ventilated storage space in the attic. The storage can be emptied once every year and be used by farmers as fertilizer. Unfortunately the thought of a dry toilet is not an option for many people.

REUSE OF WATER



Electricity

There are multiple choices of getting electricity from renewable resources. The common division is called 'on-site' and 'off-site'. The first group encompasses the system installed on the site, either on the building or on the ground attached to the building. Off-site includes the systems that are placed outside the boundaries of the building site. This system can either be a property of the building owner or a purchase of generated electricity from a company.

The most common on-site technology is photovoltaic panels. These panels generate electricity through sun rays. Another option is to place wind turbines on top or next to the building depending on the scale of it.

Off-site renewable energy can be reached by joining a wind turbine co-op. The size and predicted lifetime of a full scale wind turbine gives it an economical advantage compared to a smaller more expensive on site version (Marszal et al. 2012). Another off-site option is to purchase electricity from a company that only produces energy from renewable sources such as wind, water and sun.

If you choose to install PV-panels on your building you can get up to 20% of the installation cost pay by the Swedish government and you can also get extra money when you sell the excess energy to the grid (Energimyndigheten 2016). When this new subsidy was implemented in the end of 2009 the total PV capacity in Sweden started to increase at record speed (Hirvonen et al. 2015). Even though it can feel economical viable to produce your own electricity the payback time is seldom less than 20 years. In Finland where there is no systematic subsidies, PV electricity is not profitable for a residential user during a reasonable system lifetime. After 20 year the predicted degradation of the system is estimated to less than 86% of the original capacity. It is instead recommended to join a shared system (Hirvonen et al. 2015). The second problem with installing PV panels on-site is that the sun and electricity demand does not match in the Nordic countries. The long days in summer and the high energy demand in the dark winter is not a perfect match. A study made in Norway showed that the annual mismatch factor was 62%. This meant that 62% of the electric demand was met by the PV production and 38% had to be imported from the grid. Only 34% of the produced electricity was used in self consumption while 66% had to be exported due to the mismatch of supply and demand. (Helge et al 2014)

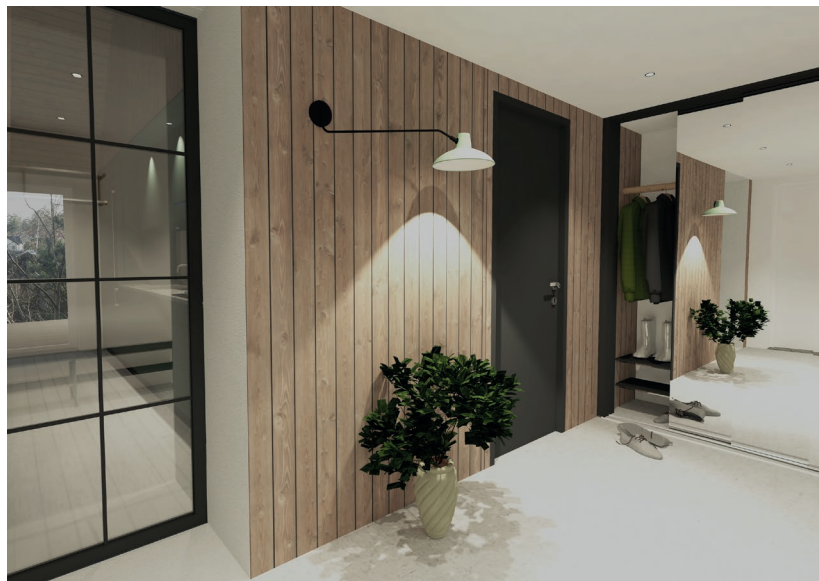
The size of the building and the amount of households' matter. For a one family home it is better to join an off-site alternative. Due to the high wind load, windmills are very popular in the area chosen for the design task. The local energy company of the municipality is called Södra Hallands Kraft. It is owned by its customers and all profit goes to improvements of the company. They only offer 100% renewable energy and around 15% comes from the local windmills. (Södra Hallands Kraft).

DESIGN PROCESS

Final design



Building on site viewed from the street



Entrance - Kitchen to the right and door to cold storage to the left

Design presentation

My first two design proposals were aimed to save energy. The features can be spotted by the compact design and the big south facing windows. When I slowly realised that a building does not have to be air tight and compact to create a good indoor climate I started to spread the rooms and instead I choose a strategy with focus on the site and the position of the different building parts.

The entrance is sheltered on the outside by a wind-breaking walls of wooden panel and a suspended roof. It is placed on the most vulnerable side of the main building and protects it from wind and weather, while at the same time prevents the warm air to escape through the entrance door. In connection to the entrance hallway there is a cold storage which is naturally ventilated by earth cooled air. This space allows the residents to store food, as it was done in the last centuries, and replace the need of a refrigerator when the temperature allows it. The living-room and kitchen can be separated by a sliding door but are connected through the high ceiling which allows the air to move freely through the rooms which is especially important when the fire burning stove is in use. The garage has heating installed and can be transformed into a living area when the car is no longer a necessity. The bedroom and big bathroom is placed in an angle to create a better environment on the south facing terrace since the wind often blows from east or west. Attached to the bedroom is a green house which works both as a buffer zone between the outside air and the inner room and it also allows the residents to grow their own vegetables. A window connects the bedroom and the greenhouse and allows preheated fresh scented air to ventilate the room in the morning.

The annex building is placed in an angle from the main building. It is positioned there to break the wind and provide insight protection from neighbours. The building is equipped with a bedroom, bathroom and hobby-room with a small kitchen. This flexibility allows the residents of the building to rent out this part of the house when there is a need for it. I believe that it is useful especially in the summertime concerning the position and rumour of the village to be a popular summer destination.



Kitchen



Living room

Discussion and reflection

- What do I need to think about if I want to design an ecological sustainable building?
- What are 'healthy materials' and how do they and different building techniques effect the design?

The remaining question is:

Is it necessary that the building is one hundred percent energy efficient and if so, can this be done by using only healthy materials?

A building can be energy efficient solely by using good materials. It might be less cost efficient and will therefore be the opposite of what energy classification was all about in the beginning. It is hard to meet the passive house requirements with a building of this size. This is because of the rate between building envelope and inside living area. To make a building of this size meet the passive criteria a big amount of insulation is needed, and it is not always motivated from an environmental standpoint. The same principle goes for a classification of a zero energy house. It is possible to cover the roof in photovoltaic panels but the energy will not be enough to meet the consumption during the long dark winters. Instead I focused on how to best provide heating to the household by the use of a heat recovering air to water heat pump, solar collectors and a wood burning stove. By using different alternatives the heating can be regulated easier during the year and change of seasons.

When I started this project I had an idea of calculating the energy performance of the final outcome. To make a life cycle analysis and put the design in different programs to measure its performance and then compare it to a 'normal' building. Passive- and zero energy buildings are in many cases used as business strategies rather than thinking about these buildings' environmental impact as a whole. Many times, the ambition only lays in fulfilling the numbers so that the building can receive its label. What many people do not think about is what materials their thick walls are constructed of and/or how well the solar panels can be recycled in the end of their lifetime.

The green labels rarely do not see the building's metabolism as a whole; of what is produced, transported, maintained, dismantled and reused.



Bedroom



Bathroom

Instead they focus on the energy that is used in the building during a very brief time span which gives the users a misleading picture of how 'green' their building really is.

Therefore I choose not to calculate values on my building and instead go for what I know is healthy materials and energy productions that are durable and recycles the already produced heat from sources such as humans and house appliances.

Process

The working method I choose allowed me to research and reflect about what I read to know what I would include in my design and why. I found most of the information in books and peer-reviewed articles online. The more I searched the more I realised that this subject was not a new topic of the 21st century. Even books from the 1970s started with an intro concerning the objective: "We need to rethink how to build to be able to save our environment". Which makes one wonder why we have not changed the way we choose to build already.

Some of the books were extra interesting such as The Whole Building Handbook written by Maria Block and Varis Bokalder. It covered almost everything about ecological sustainable building and I can warmly recommend it. Some other books were not so pleasing and it took me many pages to find what I was looking for. Even though I found the information I was looking for, I needed someone to put it in a perspective and reflect the information I had gathered. I therefore booked the interviews.

The interviews changed, and shaped my perspective, as well as giving me depth to the hard facts that I had been researching before doing the interviews. I sometimes did not agree with them and it was interesting to see how they all strive towards the same goal but with different methods and they are all equally right in their own way. I choose to make a qualitative research instead of a quantitative because it was their stories and experiences that I was looking forward to hear more about. I find it interesting to know what drives people to care for and work towards making the earth a better place to live on.



Terrace



Annex building - Hobby room

Conclusion

To build an ecological sustainable building is to care about the surrounding environment and ecosystem and to make conscious decisions when it comes to materials. It is not about quick fixes and momentarily energy saving, but to be able to see the building and what it is made of from the beginning to the end of its life-cycle and how it interacts with its surroundings.

'Good materials' can sustain for a long time, are easy to repair and can be reused or recycled. They are to be found close to the building site to minimize transportation emissions and demands a minimum of energy in the production phase. 'Good materials' does not contain any hazardous substances that are unhealthy for both human beings and animals.

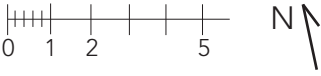
The choice of building strategy and technique is important for the composition of the whole building; how it will perform and how long it will last. By placing the building strategically in a right manner on site and take advantage of the nature's ecosystem services the use of energy can be lowered and so can also the energy used for maintenance and reparation.

A building does not have to be 100% energy efficient, but it should strive to only use energy from renewable sources and take full advantage of the free energy given from the nature. I believe that the most important thing is to see the building for what it is made of and question every single building part and construction method. Where does it come from? How is it made? How far does it have to travel? How much maintenance and repairing will it need during the building's estimated lifetime? What will happen when it is not needed anymore? If all these questions can be answered with a clear conscience for you and for the world you are living in, then I believe the building is ecological sustainable and that is the way we should design our buildings in the future.

SITEPLAN
Scale 1:800



PLAN
Scale 1:200



ELEVATIONS
Scale 1:200



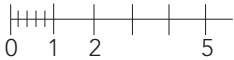
NORTH - seen from the road



SOUTH - seen from the garden



EAST

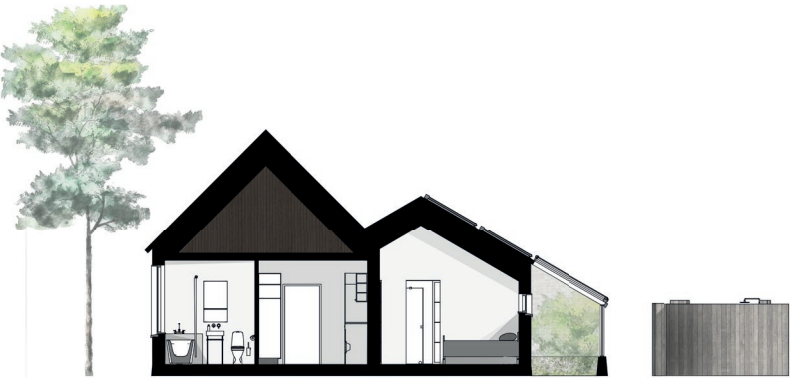


SECTIONS

Scale 1:200



A-A



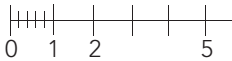
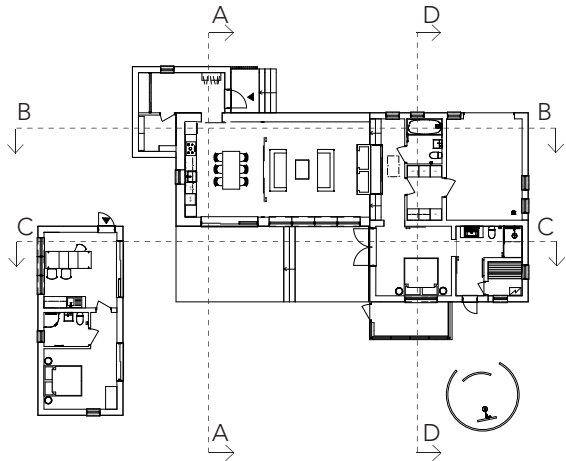
D-D



B-B



C-C



REFERENCES

ARTICLES

- Brandt, Katarina. 2014. *Så Byggs Faltak Och Spåntak*. Tidningen Trä 14(4).
<https://www.svenskttra.se/tidningen-tra/2014-4/sa-byggs-faltak-och-spantak/> (Retrieved on 2017-03-05)
- Geving, S., Lunde, E., and Holme, J. 2015. *Laboratory Investigations Of Moisture Conditions In Wood Frame Walls With Wood Fiber Insulation*. Energy Procedia 78: 1455-1460.
DOI: 10.1016/j.egypro.2015.11.170
- Gullbrekken, Lars, Geving, Stig, Time, Berit, Andresen, Inger. 2015. *Moisture Conditions in Passive House Wall Constructions*. Energy Procedia 78: 219-224.
DOI: 10.1016/j.egypro.2015.11.609
- Hansson, Tore. 1999. *Obehandlat Trä På Fasad*. Träinformation - en tidning om trä 13(3):16-19. <https://www.svenskttra.se/tidningen-tra/1999-3/> (Retrieved on 2017-03-14)
- Helge D., Tor, Houlihan W., Aoife, Georges, Laurent, Mellegård, Sofie, Time, Berit, Haase, Matthias, Maltha, Mette and Lien G., Anne. 2014. *A Net Zero Emission Concept Analysis Of A Single-Family House*. Energy and Buildings 74: 101-110.
DOI: 10.1016/j.enbuild.2014.01.037
- Hirvonen, Janne et al. 2015. *Renewable Energy Production Support Schemes For Residential-Scale Solar Photovoltaic Systems In Nordic Conditions*. Energy Policy 79: 72-86.
DOI: 10.1016/j.enpol.2015.01.014
- Fares, Amina. 2012. *The Effect Of Changing Trombe Wall Component On The Thermal Load*. Energy Procedia 19: 47-54.
DOI: 10.1016/j.egypro.2012.05.181

Jelle, Bjørn Petter. 2011. *Traditional, State-Of-The-Art And Future Thermal Building Insulation Materials And Solutions – Properties, Requirements And Possibilities*. Energy and Buildings 43.10: 2549-2563.
DOI: 10.1016/j.enbuild.2011.05.015

Kundakci Koyunbaba, Basak and Zerrin, Yilmaz. 2012. *The Comparison Of Trombe Wall Systems With Single Glass, Double Glass And PV Panels*. Renewable Energy 45 :111-118.
DOI: 10.1016/j.renene.2012.02.026

Marszal, AJ, Heiselberg, P, Jensen, RL & Nørgaard, J. 2012. *On-Site Or Off-Site Renewable Energy Supply Options? Life Cycle Cost Analysis Of A Net Zero Energy Building In Denmark*. Renewable Energy 44: 154-165.
DOI: 10.1016/j.renene.2012.01.079

McGarry, Brian. 2013. *The Active Advantages Of Passive Housing*. OECD Observer no 297. http://oecdobserver.org/news/fullstory.php/aid/4287/The_active_advantages_of_passive_housing.html (Retrieved on 2016-12-19).

Suresh B., Sadineni, Madala, Srikanth and F. Boehm, Robert. 2011. *Passive Building Energy Savings: A Review Of Building Envelope Components*. Renewable and Sustainable Energy Reviews 15.8 (2011): 3617-3631.
DOI: 10.1016/j.rser.2011.07.014
In this case the B. and F. stands for a second surname

BOOKS

- Bergkvist, Per and Fröbel, Johan. 2013. *Att Välja Trä*. 9th ed. Stockholm: Svenskt trä. E-book. <https://www.svenskttra.se/siteassets/6-om-oss/publikationer/pdf/att-valja-tra.pdf> (Retrieved on 2017-03-14)
- Bokalders, Varis and Block, Maria. 2010. *The Whole Building Handbook*. London: Earthscan.
- Pearson, David. 1989. *The New Natural House Book*. London: Conran Octopus. E-book.

Sandberg, D., Azoulay, M., Baudin, A., Blom, Å., Carlsson, B., Eliasson, L., ... Thörnqvist, T. 2011. *Utvändiga Träfasader: Inverkan Av Materialval, Konstruktion Och Ytbehandling På Beständigheten Hos Fasader Av Gran Och Tall*. Institutionen för teknik: 11. Växjö: Linnéuniversitetet. E-book. <http://urn.kb.se/resolve?urn=urn:nbn:se:lnu:diva-18670> (Retrieved on 2017-03-15)

Sternberg, H. and Lanne, L. 1992. *Ekobygg*. Stockholm: Ekokultur.

ACADEMIC TEXT

Zäll, Christian. 2012. *Uppvärmning Av Fastigheter Utanför Fjärrvärmnätet*. Diss., Umeå University

LAW AND REGULATIONS

Commission Recommendation (EU) 2016/1318 of 29 July 2016. On guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings.

Samhällsbyggnadskontoret. 2017. *Detaljplan för Mellbystrand - Norra delen 2011-05-26*. Laholms kommun. <https://www.laholm.se/globalassets/upload/miljo--och-byggnadsnamnd/samhallsbyggnadskontoret/detaljplaner/antagna-detaljplaner/02-1012.pdf> (Retrieved on 2017-02-02)

SFS 1979:429. *Skogsvårdslag*.

FACT-SHEETS

BPIE. 2015. *Nearly Zero Energy Building definitions across Europe*. Brussels: Buildings Performance Institute Europe. http://bpie.eu/uploads/lib/document/attachment/128/BPIE_factsheet_nZEB_definitions_across_Europe.pdf (Retrieved on 2017-11-01)

Dr. Wolfgang Feist. 2017. *Certification as "Quality Approved Passive House" - Criteria for Residential-Use Passive Houses*. Darmstadt: Passiv Haus institute. http://www.passivhauscentrum.se/sites/default/files/international_kravspecifikation_for_passivhus_1.pdf (Retrieved on 2017-11-01)

Energirådgivningen. 2012. *Pelletsvärme*. http://energiradgivningen.se/sites/default/files/faktabl_uppv_03_pelletsvarme_dec10.pdf (Retrieved on 2017-04-02)

IVT. *IVT 840/860 Frånluftsvärmepump*. https://www.energipartner.se/wp-content/uploads/2017/04/IVT-840_860-1.pdf (Retrieved on 2017-04-02)

Riksantikvarieämbetet. 2013. *Materialguiden*. Visby: Riksantikvarieämbetet. http://samla.raa.se/xmlui/bitstream/handle/raa/3310/Varia%202013_35.pdf (Retrieved on 2017-03-18).

SP Sveriges Tekniska Forskningsinstitut. 2016. *ETA 16/0797 of 21/12/2016*. Koljern. http://www.koljern.se/_/frontend/handler/document.php?id=193&type=42 (Retrieved on 2017-06-11).

INTERNET PAGES

Arvidsson, Bernt. 2006. *Sibirisk Lärk*. Svenska skogsplantor. www.lovtradforeningen.se/cm4all/iproc.php/Sibirisk%20lärk%202011.pdf?cdp=a (Retrieved on 2017-03-18).

Birgersson, Anders. 2016. *Så Här Väljer Du Rätt Värmepump Till Villan Eller Fritidshuset*. *Energispararen*. [Blogg]. 23 March. <http://blogg.ivt.se/energispararen/valj-du-ratt-varmepump-till-villan-eller-fritidshuset> (Retrieved on 2017-04-01).

Byggfabriken. 2011. *Om Linolja Och Linolfärg - Byggfabriken - Modern Byggnadsvård: Renoveringshjälpen*. <https://www.byggfabriken.com/renoveringshjälpen/om-linolja-och-linolfarg/> (Retrieved on 2017-05-14).

Climate data. 2017. *Climate Halmstad - Sweden*. <https://climatedata.eu/climate.php?loc=swxx0008&lang=en> (Retrieved on 2017-03-20)

Energimyndigheten. 2016. *Stöd till solceller*. <http://www.energimyndigheten.se/fornybart/solenergi/solceller/stod-till-solceller/> (Retrieved on 2017-08-27)

Energyplus. 2001. *Weather Data Download - Goteborg Landvetter 025260 (IWEC)*. National Renewable Energy Laboratory. https://energyplus.net/weather-location/europe_wmo_region_6/SWE//SWE_Goteborg.Landvetter.025260_IWEC (Retrieved on 2017-03-21)

Hasopor.se. 2017. <http://www.hasopor.se/> (Retrieved on 2017-06-11).

Hunton. se. 2017. *Dokumentation*. <http://hunton.se/dokumentation/> (Retrieved on 2017-05-05)

Informer Technologies, Inc. 2017. *Climate consultant 6.0*. <https://climate-consultant.informer.com/6.0/> (Retrieved on 2017-03-20)

Ingemarson, Lars. 2017. *Kommunfakta - Laholm*. Laholms kommun. <http://www.laholm.se/om-kommunen/fakta-om-laholm/> (Retrieved on 2017-06-03)

Lundby, Anna-Lena. 2017. *Detaljplan - Mellbystrand*. Laholms kommun. https://www.laholm.se/bo_miljo_trafik/planer-och-utredningar/detaljplaner/gallande-planer/mellbystrand/ (Retrieved on 2017-10-15)

Lundström, Petra. 2016. *Isolera Med Ull*. Lantliv. <http://lantliv.com/vi-gillar/isolera-med-ull/> (Retrieved on 2017-02-26).

Polarpumpen.se. 2017. *Guide Till Frånluftsvärmepump*. <https://www.polarpumpen.se/varmepumpar/franluft#franluftsvarmepump> (Retrieved on 2017-04-02).

Saviukumaja. 2017. *Clay plaster*. <http://saviukumaja.ee/en/clay-plaster> (Retrieved on 2017-03-05)
Svenshults såg. 2017. *Optimera förutsättningarna för lärkens rötskydd*. <http://svenshultssag.se/lark/> (Retrieved on 2017-03-05).
Sweden Green Building Council. 2017. *Miljöbyggnad*. <https://www.sgbc.se/om-miljoebyggnad> (Retrieved on 2017-10-24)

Sunearthtools. 2017. *Sunposition - Mellbystrand*. https://www.sunearthtools.com/dp/tools/pos_sun.php?lang=en (Retrieved on 2017-03-20)

Södra Hallands Kraft. 2017. *Kundägt energiföretag för El och Nät*. <http://www.sodrahallandskraft.se/> (Retrieved on 2017-08-27)

The Engineering Toolbox. 2017. *Thermal Conductivity Of Common Materials And Gases*. http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html (Retrieved on 2017-02-26).

Träguiden. 2003. *Grundläggningsdjup - Grunder*. <https://www.traguiden.se/konstruktion/konstruktiv-utformning/grundlaggning/grundlaggning-grundlaggningsdjup-grunder/> (Retrieved on 2017-04-29).

Träguiden. 2013. *Tak*. <https://www.traguiden.se/konstruktion/konstruktionsexempel/tak/> (Retrieved on 2017-03-26).

Villa Circuitus. 2017. *Konstruktionsritningar*. <http://circuitus.se/projektbeskrivning/konstruktionsritningar/> (Retrieved on 2017-12-27).

WWF. 2017. *Cotton Farming*. http://wwf.panda.org/about_our_earth/about_freshwater/freshwater_problems/thirsty_crops/cotton/ (Retrieved on 2017-02-26).

IMAGE SOURCES:

1. Samhällsbyggnadskontoret 2017
2. Climate data 2017
3. Sunearthtools 2017
4. Informer Technologies, Inc 2017

If not otherwise stated the presented images are made by the author.

APPENDIX:
THE INTERVIEWS

INTERVIEWS

MARIA BLOCK

22 MAY 2017

Maria Block was born in 1963 on the Swedish west coast. She is a Swedish architect, author and illustrator. She has through the years become an expert on environmentally friendly materials and surface treatments and has together with Varis Bokalders written the book "The whole building handbook: How to Design Healthy, Efficient and Sustainable Buildings".

C: Who are you and how did you get your interest in working with ecological and sustainable buildings?

M: Environmental issues caught my interest quite early actually. They build a nuclear power station called Ringhals close to where I grew up and this awoke my interest in the field. We did not have any specific education in the subject at my architecture school; Chalmers. I was employed by White after my graduation and after some years I started a lunch group to discuss with others about ecological building. I felt like, ok that buildings look pretty and cool but I wanted to be able to deliver a fully worked out building from the detailing of it, to material choices and installations.

C: Could you receive any education in the subject or how did you gather the information?

M: No, we found out a lot by ourselves. After some years at White the big building crises came 1991 and no one could build anything. The result of this was that a lot of young newly employed people had to leave the offices. By that time White had 160 employees and 50% of them had to leave. That was when I thought "now when I am unemployed I can start focus on ecology". At this time I found a conference which where situated both in Helsinki and Stockholm called Ecological Architecture and I decided to join it.

At the dinner on the boat travelling to Finland I sat next to Varis Bokalders who was a professor at the Stockholm Royal Institute of Technology (KTH). He also had a big interest in ecological building techniques and both of us had been thinking that there needed to be a handbook in the subject. It was something that we both felt that we missed. Said and done, since I was unemployed I thought that "I can move to Stockholm some months

and write this book and then I move back and continue my life on the west coast". What we did not know was that it would take 4 years before we could release our first book in 1997. The first book was a compilation of 4 smaller books. We realised by time that it should not be as easy as we initially thought. By this time I managed to create a network in Stockholm and since then I have stayed there.

C: What do you believe is necessary to be done so that architects and clients will be more aware of their choice of materials in buildings?

M: I believe that legislation is very important. The politicians have an important role to play. Hormone disturbing substances will not disappear until we put forward strict demands. Unfortunately I think that this will be the only way. But then there is always this clique that wants to be frontrunners, the people you and me are part of, who really wants to make it happen. These people research the materials before they make a decision and choose better options if they would be found to have harmful substances in them. It is time consuming and you have to work for it. But you also need to be aware of that what we find harmless today might be found harmful in the future. The science is changing all the time and new substances is found as we speak, chemicals is a jungle!

I do believe in legislation. But these environmental classification systems... Many builders want to have a certificate so that they can sell their building more easily. Others do it because they are engaged and wants their grandchildren to have an enjoyable time on earth. The systems have not been good enough when it comes to material decisions. They are more focused on energy, daylight, radon, legionella etc. The demanding's concerning materials is very low. You could build almost anything and still get an environmental classification of silver and sometimes even gold class. Since it has not been any demands on electricity and plumbing the classification is misleading. People believe they buy a highly environmental classified building and believes they do good. The buildings are better than others in some ways but they can still contain a lot of hazardous materials.

C: What do you believe is the biggest barrier to why we are not doing more to solve it? Is it economical requests from the builder or is it the architects that does not propose the use of healthier materials?

M: I believe that everyone needs to be more aware. It has happen so much since the nineties when I started. By then we were really seen as nerds. Today sustainability is a well known subject. When I am bringing the question about ecology in meetings today people are aware that

they need to change their way of living, being and build. Otherwise it will not work out in the future. But from this meeting to when the change is really happening in the built environment they are still many steps to take.

C: *Today there are many builders that draw buildings with prefabricated concrete and glass wool insulation, why do you think that they still do that?*

M: I believe that there are not so many people that knows about cellulose insulation and so on. It is exactly as you say, it is business as usual. Ecological building material is right now around 5-10% more expensive than common materials and there are often hard negotiations around these extra moneys.

C: *If you do not have the possibility to build a 100% ecological building because of for example costs, what do you think should be the priority when designing the building? Say for instance a private person building his or her very first villa.*

M: I am not a fan of glass wool insulation and impenetrable plastics so I would choose to have a wooden fibre insulation board as wind stopper because it is a very important feature of the building. I would also be careful about not to choose material will hormone hazardous substances and that kind of things. I would try to work a lot with finishes and colours that are fossil free and which does not have any conservation substances that can cause allergies.

C: *What materials do you refer to when talking about hormone disturbing substances?*

M: There have been for instance a lot of these substances in plastic carpets. You should consider both the effect on the people that uses and are close to the finish products but also the effect on the people who produces the material. I would most of all like to exclude all dangerous substances in the production phase and that is why I always try to choose better alternatives. You must think about small children that are crawling around close to the floor and puts everything in their mouth. That is why we also have to think about what we buy in terms of packages and toys. Hormone disturbing substances can almost always be found in plastic things such as toys, packages and cables. Some of the substances are forbidden and instead exchange with other material, but who knows if these ones will not be classified as dangerous as well in the future?

C: *What kind of costumers do you have? Do you draw buildings or do you mostly work with consulting?*

M: We have a very broad customer group. There are a lot of aware private

customers that call me for help after they have read the book. They are often highly educated and well-grounded before they take contact. I have tried to work less with private customers though. I want to be part of the building of cities. I do consulting for a building company that focuses on wooden buildings. I am their expert in choosing material and installations and all kinds of stuff. I really like that because it feels that I can reach a bigger target group.

I want to raise the volumes on wooden buildings. When looking at residential buildings 90% is made of concrete and only 10% in wood. I believe lack of knowledge is the biggest reason for this. There need to be more journalists that writes about it, architects that wants to work with it and that everyone starts talking about it.

LARS-ERIK MATTILA

24 MAY 2017

Lars-Erik Mattila was born in 1982. He is a carpenter and an architect. He began his studies at the University of Technology (today Aalto University) in Espoo 2005. He is currently working in an architecture office in Helsinki and he holds lectures about healthy building habits in the building department of Aalto University. Mattila is interested in the renovation of old buildings and he is currently working on a housing project where everything will be made of only five things: stone, wood, lime, glass and steel.

C: First I would like to ask the standard questions, who are you and what do you do for living?

L: I am Lars-Erik Mattila I am an architect and cabinet maker. I work as an architect here in Helsinki.

C: Is the office that you are working at specialized in something particular?

L: It is, it specializes both in restoration of historic buildings and new buildings which takes advantage of best practices of older buildings. My job at the moment is actually an extension of my master thesis. I am making a smaller version of it, a row house sized project. Which in short does not contain plastic or chemicals or anything it is a very minimized palette of materials. Basically we are making everything out of five things; stone, wood, lime, glass and steel. Mostly wood though. We are right now in a negotiation phase, we are going to the authorities next Monday. For the moment it is not possible to build a house like this so that it meets regulations so what we have going is an experimental building permit. It is a way to go around the legislation.

C: Why is it not legit?

L: At the moment the regulations, even though they aim for sustainable buildings, are creating a bottle neck because they emphasize momentary energy efficiency. Take a sports car for example. It might be fantastic and amazingly energy efficient once you put it on. What is not taken into consideration is the amount of energy that was needed in the production, what it is made of, how long it will last and how you keep it running. I think that is far more important than how much it consumes when it is on, right now, today. So that is the fundamental flaw at the moment

in the legislation. Buildings reflect the legislation, of course, that is what the legislation are meant for. But if the legislation is screwed or there is something wrong with it, it will show up in the buildings and that is what we have in the moment. And it is not only that, according to the legislation it is also illegal to build in a different way. What makes this almost humoristic is that we have buildings today, that work in a totally different logic; the old buildings. Those buildings at this moment are not taken into consideration. Even though they can be proofed to be very energy efficient.

Buildings are radically different from each other. It is the same as calling a bunch of humans as people. 'People' counts for a vast variety of various kinds of humans. However old people are still made of flesh and bone, they have similar metabolism. Buildings however do not. Buildings that are, let say, built before second world war and after (the division goes roughly around the 1950s) are radically different from one and another. They share no similarities other than that they have rooms, windows, doors and people live in them. They are made of completely varied materials and they have another logic behind them. Therefore, when we say 'buildings' it might be anyone of them and that is why people ('people' ha-ha) starts practicing one type of logic into a building with a totally different logic. Meaning that from a contemporary building perspective, old buildings are crap. They are not energy efficient enough, they are expensive to maintain, (even though it is very expensive to maintain new buildings as well). The perspective from current legislation is so that old buildings seems crap. So they need more insulation, better ventilation, heat recovery, they need all kind of stuff and new buildings are great, or at least they fulfil the requirements. It is funny when we consider that there is a big amount of satisfied people living in these 'old crappy buildings' and in Helsinki these buildings represent the most valuable ones. I see this as one of the big reasons that the discussion does not happen or lead anywhere because people are already mixed up in fundamental terms.

C: Why did you become interested in restoration of old buildings and fundamental building practice?

L: I ran into a dead end with current building practices. Nobody will probably say that they are against sustainability but the talk and the walk are radically different. My interest started before I started studying architecture. I am from a generation where since the first grade I have been taught in school that if everybody lives as we live now we will need multiple planets. So basically I know it, but then again like everybody

else, everybody knows but no one is doing anything about it. That has continued and still continues.

My path to where I am now probably has to do with this book *Talotohtori* by Panu Kaila. Panu is a spoke person for sustainable buildings. This was a popular book among architects for sure but it was also written for the general public, it was popular science. He dealt with issues concerning how people treated old buildings. That they put in extra insulation, they have done this and that, and he had a great analogy that houses are not like people etc. Panu provided something that made current building practices seem problematic which until that time was not on the table. Through him I discovered that there is something wrong with the mismatch between how old buildings are made and new. I got this book as a birthday present a couple of years before I started studying architecture, I was around 22-23 years old. I felt critical about the stuff that we were taught at architecture school. For example, history of architecture. It was a story of development. First came one thing and then came something better, and it peaked when Corbusier and his friends came into the scene. It is just a story of men designing fancy buildings. There was something that did not seem right but however there was no alternatives presenting so it was just a feeling back then. Later there was a couple of courses happen, optional ones but non-the less. Panu Kaila did not only held talks and wrote text he also held courses in architecture schools. The courses had a 'hands on' approach. He even taught in how to create your own paint and about chemicals. It had a scientific approach. Panu Kaila never taught me, he retired before I started school. But his students took up the course and they ran with it. It was a fantastic course. Translated from Finnish it would be called something like 'buildings and restoration'. The best part of it was not only the lecture series but there was these workshops and restoration camps. When I joined the camp had already been going on for a few years. The camp was going on for about ten days. We worked with restorations of old buildings such as saunas and small cabins. To examine the building we started to take the building apart until we found the spot that was damaged and by simple tools documenting this in a pen and paper style. By examine the damage we tried to understand what had happened. The key thing was that we made a replacement piece in the same way as the original piece was created. Which meant that we took a few step back saw a tree, took it down and peeled it. By trying to create that replacement bit we learned so much in the process that we could not learn from a bench in the school. This was the way how

people learned how to build back in the days. It was amazingly elegant how all the materials came from less than a hundred meter radius. They were very lightly processed, you do a lot of selection but very little effort. You look around and say 'I am going to take this tree and not that one. They did not have to teach any of that and that was the biggest bonus ever because our job was just 'make another part like this one here'. Nobody had prior experience, the teachers did surely, but I think that probably 80% of the students bought an axe afterwards because it was probably revolutionary for many to realize that I can actually build something without drawings. It did not make the rest of my education worthless it is just that this is information that I can take advantage of in my work and see the connection between actual labour and the design and see how far they are from each other at the moment. This was the moment when I stopped looking at old buildings as 'old' buildings. I kind of forgot the timeline on purpose. Everything I know about historical and vernacular buildings became like a textbook or manual. Then came the day when I started my thesis project which went with this logic, it was an enjoyable experience to design it and I felt very comfortable about it. But the thing was that then I started to thinking that 'wait a minute if this is so simple and good in so many ways then why are we not already doing it?'. There was another lecture held by Kimmo Lylykangas. He was another important figure. Kimmo had another course with a scientific approach. He taught a course which was a competition to make a sustainable building, it was called 'the next generation's sustainable building' and it was held in Japan. It was after I had done the restoration camp and the theme of the competition was to design a new building. It was around the same time that we built the Luukku house. It was executed in Aalto in 2010. The Luukku house was a small solar-panel-covered wooden box, made out of wood based materials. I was part of that project too. So maybe it was these three things; the restaurateur camp, being part of the Luukku house project (just helping out I was not designing it or anything but I went to Madrid to put it up) and then the competition in Japan. When I was working with the Luukku house I saw the complexity of a 40 square meter big house which cost 600 000euros, and it was filled with gadgets. For a house that small it had a formula one style ventilation system, top of the line machinery, everything was monitory controlled and it had an iPad app from which you could finger through the house. It ran with solar energy and it produced more energy per year than what it consumed so it was a plus energy house. Anyway it was the 'perfect'

house. The best house anyone could think of, it checked all the boxes, it was awarded with all kind of prizes. At the same time the more I looked in to it I thought that if this is considered the very best building then we are doomed!

You can sustain an old building but you cannot sustain the Luuku house. I realized that the main objective was to get the building up and running but not how to run it.

Then came the competition in Japan and I was in a team where there was maybe three or four engineering students and the rest were architects. We were a rather big team of eleven people and it was only me and Joonas from Finland. We went through a lot of material concerning sustainability. Kimmo is a great teacher, he is not like "google sustainable and see what you come up with and look at cool pictures", no he had a different agenda, he could see through categories of different objectives and he left the actual footwork for the students. The competition was directed towards energy efficiency and we solved our energy supply with a micro combined heat and power plant. It is sort of a mini version of Helsinki's district heating power plant. It works in such way that you put fuel in it, wood pellets or coal or something similar, and it produces electricity and heat. The ratio is about 20% electricity and 80% heat. During summertime the electricity runs it and during wintertime the heating runs it. This means that during summer there is surplus heat and during winter it is surplus electricity. The CHP plant is only one or two square meters big, it is like a boiler but has a sterling engine in it which runs with warm air. In our project the plant would run on wood pellets, we called the project the Five Tree House because the engineers made a calculation that it would require the amount of wood pellets which equals five full grown trees per year per a 100 square meter house. The excessive heat in the summer could be used for heating a pool for example or heat the outlet pipes to boost natural ventilation. Our starting point was to see how it is done today and the solution is to do exactly the opposite, at least try it.

After these projects where the main theme was energy I realised that it is not all about energy. Sustainability was defined by the architect Bill Reed as "If you can do it forever it is sustainable and if you cannot it is not". It is so short but still hard to deny. If someone says something is sustainable than you should ask "can you do this again? And again? And again?". It takes just seconds to think about it and you can look around us and see that nothing will pass this test, well the trees will! Putting some more Styrofoam to save energy by creating an airtight building

is a lot of bullshit. It means that the fundamental problems are being seriously avoided. Either people are stupid or mean. Architects dealing with sustainable buildings should not be neither of it. However it is easy to end up on the wrong side because there is not much help available if you are looking at the way people are being taught. If we as professional architects will not see it no one will. Which then leads me to what I am doing now. Since the way we are building now is totally unsustainable that is not an option for me.

C: What do you think it takes to make architects and builders think more about sustainability and why do you think will change our way of designing and choosing better materials?

L: Well if you do not see a problem in how things are at the moment you have no initiative or no need to change things. So in a way you need to be on the suffering side.

C: So how do you motivate people?

L: Well I do not start with them. When there is a problem see who benefit from it and do not start your work with them. You start with them who suffering from it because they are motivated to do something about it. Now that I have been teaching I have got a lot of feedback from students that "why did they not teach us these things in the first year? After doing wrong for five years, NOW I get this information". Teachers that are writing the curriculum have got their education in a time when these issues did not exist in the same way and the education then reflects that. It will take some time until it reaches the agenda. That is the motivation for me to continue teaching.

C: So you think education is the key?

L: Through education yes for architects. Because in school and academia it should be that people make choices based on the best arguments, not according to who is paying the most. In business it goes the other way around. The authorities should work the same way as university students; look at the best argument and make the legislation according to that. If it was like that business would flow with that. However right now there is a really difficult situation where business is both calling the shots on education and legislation.

The way sustainability should be represented is that you have the environment which contains society which contains economy. This is the regular world view from my point but at the moment everything starts with someone with a lot of cash. So, the economy runs things in the end. Even though it should be from a completely reversed starting point. The

economy should just be a tool for the society and initiating things, I mean money is just an agreement it is nothing real. Just as carbon dioxide numbers on products are just a price tag. If your shirt costs 600 euros or 800 euros does not tell anything about your shirt.

The buildings are now tools to make money, within restraints of legislation and with makeup of ecological crap so that people will think that it is good. Looking more closely at buildings we can see fundamental problems in our society, so they are all tied together. I do not even have to think about a different society I just have to change parameters in the building, make stuff well. Then think about 'okay so this is the product, what kind of society does it need to be built and what I did was not to go deep into this stuff, I just pointed out the problems and then I presented a new building. This just quietly presents a different society. It presents initiative for change by just showing the end product. In a way, this is the stuff that we should be making, let us do things so this happens and that is what happenings now. Legislation is changing but it changes slowly through compromising etc, but from next year on it will be way more possible to do my master thesis so that it meets the requirements. Natural ventilation is back on the agenda which it has not been for a long time. Basically, the officials can say that" this does not meet the logics of what we do now, you cannot have it".

In Finland there are three men, running the legislation for restoration and new buildings. Their education and world view prevents them from seeing things that are right in front of them. I know they are all living in old houses with natural ventilation. Some of them, let say, live in a full brick building with natural ventilation, historical buildings in Töölö. Through the legislation that they are writing themselves, which are effecting everyone that lives in the country, it would not be possible to construct a building like that of what they are themselves living in. They do not even know how their own environment works. But their education prevents them from seeing it. Before you started to studying architecture you might saw the buildings differently, now you see things. Buildings are not only windows and walls, you can now look deeper and it has to do with your education. My education has transformed my view of how I am looking at building regulations.

C: My thesis design is a rather small project and this question does probably not make sense anymore but If you do not have the possibility to build a 100% ecological and sustainable building because of for example costs, what do you think should be the

priority when designing the building? Say for instance a private person building his or her very first villa.

L: It depends on what kind of restraints there are. If someone is willing to put their own effort in to the construction work is not difficult. Modern construction work like installations are difficult but making a building as it has been done for thousands of years is not difficult. The materials are already there. That is the least problematic way. However, what brings the problem is when people start thinking" I can't do this!". It has to be about values and not money. They have to face that if the money runs the show it will contradict the most ecological thing. So first start to see if it can be done within the ecological restraints and then see how you can solve the money issue. The products do not need to come from a drop-down menu. It does not have to have a label or a CE mark. I do the food analogy; you can make excellent simple good food without touching processed food. If legislation only leads to make processed food and if your education as an architect or your situation at the moment is about choosing frozen pizza or ice cream and trying to put these together, you can check that they have enough energy and enough calories, they are suppose to be good, but how can people then still be fat?

KIMMO LYLYKANGAS
17 NOVEMBER 2015

Kimmo Lylykangas is a lecturer and an architect. His studio in Helsinki has an expertise Kimmo Lylykangas is a lecturer and an architect. His studio in Helsinki has an expertise that covers energy efficiency, passive housing and wood construction. They have won several prizes in these categories. Kimmo has also held lectures at Umeå School of architecture and at Aalto university in the theme of sustainable building techniques. This interview took place two years ago, in the very beginning of my master studies when the terms of sustainability was all new.

C: Imagine you have a house, an apartment building or a villa, and you want to make it more sustainable but you can only do one thing, what would that be?

K: If you refer to energy efficiency it might be the ventilation and heat recovery. I think energy efficiency and sustainability are two separate things. It is not a simple question to ask. I think the first thing is to analyse what are the components that needs to be renovated for technical reasons. Then you renovate those that are in the end of their life. So, let us say if the walls have 20 years left, it does not make any sense to renovate them. In that case you should wait until it is absolutely necessary and by then you can also upgrade them. But upgrading only for energy efficiency usually does not make any sense. So it is all about analysing what is the current state of the building and then you respond to that with your plan. In a typical let say 60s building the energy consumption is quite high and to upgrade with an exhaust air fan makes a lot of difference. Now they blow all the heated air out when it can be reused instead.

C: What do you think the main focus should be when you design a passive house?

K: Well passive house already as a term includes a certain strategy; it says that you are saving energy and you are saving it by passive means and you save it by improve the building's envelope and heat recover the ventilation. So passive house is about heating energy demand and for example heat pump does not help you with that. So if you choose to build a passive house you have already chosen your focus or pallet of tool kit that you work with.

C: Which are the main heating sources except from the users and household machines?

K: Passive house is a strategy where you first try to reduce the heating energy demand and then you meet that demand with some energy resource. This could for example be a small heat pump but once you have chosen to work with passive houses you have already chosen to work with thermal insulation, air tightness, maybe passive solar also and heat recovery. Basically, you will have exhaust air ventilation so certain choices are done already when you choose this energy efficiency target. To illustrate the possibilities you might also choose otherwise like aiming for very low CO2 emissions of the maintenance and the energy use of the building. That you might do with different kind of methods. You might chose to, let say, have a pellet burner. You build a pellet boiler and you get very low emissions for your building to heat it up but you might still work with natural ventilation. You might not need to have any extra thermal insulation it could be a standard house but you still get very low emissions. But with passive house you already make a choice to work with building envelope. Especially here in the north to get down to the figures that are required. To be able to call your building a passive house you need to have a good thermal envelope. So my answer will be thermal envelope. It is another story if that is an awareable strategy. There are several shortcomings in a passive house when it comes to the zero-energy target. One is the means that if you build a very small building it is quite difficult to make it a passive house in the north. Because the figures are the same for big buildings as for small buildings so a very large building might accidentally become a passive house here in the north. With a very small building, let say smaller than 100 square meters, it is extremely difficult to reach these numbers.

C: To make a passive house you have to meet certain figures?

K: Yes it is performance based. So to be able to call it a passive house you have to meet these figures. The original definition was that the heating power needed to be less then 10kwh per square meter. These new buildings would be cost optimal. Instead of wasting heat power, the heat in the outlet air would reheat the building again.

This was the original Swedish idea for passive housing by Hans Ek, Bo Adamsson and Wolfgang Feist. Wolfgang Feist later went to Germany and started the passive house institute. He changed the criteria so that it should be 15kwh/sqm. He focused only on energy and the idea of ventilation heating was abandoned. When he did this he also abandoned

the idea of making a building cost effective, now it was all about numbers. These numbers do not have a scaling so they are the same for small building as for bigger ones. Do you know why it is more difficult for smaller buildings to reach these criteria?

C: No?

K: The reason is that in a small building you have a lot of building envelope surface area. So the heat-losses per one square meter are quite high. In multi storey houses you have a lot of apartments and a compact volume so the heat losses are much less. The larger you make the building the better this ratio between the floor area and the heat loss envelope area is. A villa design is a mistake in the target settings. Basically it means that if you build a 400sqm single family house, you can build a passive house and call it energy efficient but then again you are building a lot of square meters for one family only. The same family could live in 200sqm but it would be more difficult and expensive to make it a passive house.

C: What is it that makes it more expensive?

K: In a small unit you have such a big surface area that causes heat losses so you need to compensate that with more thermal insulation and higher heat recovery rate. In our climate you need all the possible means you can think of to make a small building a passive house and the costs are about 20% more whereas a multi-storey house can be made as a passive house without any additional thermal cost. So it is a technical specification for passive houses but what it really means in practice is quite complicated.

C: What is the difference between a passive house and a zero energy house?

K: The passive house as a target means that you have reduced the energy demand to a certain level so you are trying to get good thermal comfort and use little energy. In zero energy building in addition you are generating energy for yourself and also for the grid. So in zero energy building the definition is based on annual energy balance. Zero means that in one year you purchase certain amount of energy that you need to run your building, that is the basic definition. In a passive house you do not need to produce anything you just reduce your consumption to a certain level. What they have in common in practice is that most of the zero energy buildings are based on passive houses but you just add the photovoltaic on the rooftops. That is basically how they do it. Before all zero energy houses were built like that. First they were trying to reduce the consumption like the passive house part and then they invested in photovoltaic, some solar collectors but mostly photovoltaic

that produces electricity. This electricity is partly used in the building and partly send out to the grid.

C: And if you want to make a plus energy house?

K: Then you just need to invest more in photovoltaic, it is quite simple. You just need to produce more than you consume during one year.

C: But you still have the passive house as a basic?

K: That is a good starting point. You can also make any building a plus energy house you just need more photovoltaic to compensate the higher consumption. So this is the practical reason why most zero houses are passive houses at the same time.

C: So, what is best; passive house or zero energy house?

K: I am criticizing them both. They are most inadequate targets for a sustainable building. Neither one of them asks how much CO2 emissions we are actually causing to the environment. The problem with passive houses is that the figures that they are based on are based on this idea of cost optimization but if you take that further north it is not cost optimal anymore. To reach the same figures in the north cost you so much more that you cannot really say that this is a good target, at least for a single-family house. It doesn't render any viable emission target that would be based on environmental sustainability targets. It just started as an idea as cost optimal and then it went around Germany, Sweden, Finland... The original effort was the investment and maintenance cost. I think we should look at the environmental performance. What does it do for the environment. A passive house does not say anything about that. And also with zero energy you can say that 'yes I am producing as much as I am consuming over one year' but it is not free of emissions. Because if you do carbon footprint calculation for a building like that it is like a game of compensation. Still you need to heat up the zero energy building in the wintertime and you are causing some emissions which are very high in Finland but very less in Sweden. And then you start compensating that with your photovoltaic. But there is really no one that wants that electricity in a summer day so it is a quite abstract game of numbers.

C: But is it not better than a 'normal' house?

K: I would not say so.

C: Is it because you use more material to reach this zero energy goals?

K: I think it in a way combine two things that might not be wise to combine. The first is that yes your building should consume less, that is wise, but then it says that you need to produce some electricity to

the grid. Well I say that it is not wise because all the buildings are not in a very good place to produce energy, It might be wiser to say that energy companies can produce electricity by photovoltaic energy and they can put these panels on optimal sites, there will be a professional person to take care of them and they will be owned by a professional that will distribute it more effectively. Now we are telling builders that you should pay the photovoltaic, that makes buildings more expensive, the apartments become more expensive and then it is us that must take care of these panels for 25 years. So I think as a strategy it is really far from being wise. I am very critical to build zero energy buildings as a target, it is quite stupid actually.

C: What do you think the target should be if not a 'zero energy building'?

K: Minimizing carbon footprint. We should talk about the damage we do to the environment and not energy. When we talk about energy it is never the same as CO2. And if you would look at the CO2 you will start talk about how we will really solve the problem. My understanding is that the whole point of why we talk so much about zero energy is that it is a European strategy. They want to respond to the climate change not only by making better buildings but also supporting the industry. To develop better products as photovoltaic panels and other technical gadgets, with which you could in a way play this game. And they think it is a boost for the economy when the industry develops new products. More viable thing would be just to say; 'Hey we would somehow need to reduce our consumption'. No we are saying that 'yeah yeah we are keeping on consuming and we develop products which will solve it'. It would be wiser to accept that we will be so many on the planet that we cannot keep on consuming this much. There will be things in technology but we cannot fully count on technology to solve all the things. I would rather look at the family and households how we can be better and how the built environment can help us consume less.

C: Well, my next question was: It the technical approach more or less equally important as good design?

K: No, it is a very stupid strategy. And if it is applied I think that it should be applied by professionals because new technology is expensive and now we are doing it not in a very nice way. We make single family house builders pay for photovoltaic if we ask them to do zero energy buildings. Instead it should be energy companies that should invest in new green technology. The professionals can produce it in a more efficient way.

I just had a key note presentation where I criticize both passive and zero energy buildings. I think they both have a randomized target and none of them are telling anything about environmental performance. Which should be a key issue.

What they in EU not really did was to combine the idea of technology and CO2 reductions. This is now served as one package, as the only way to do it. But I think there are many better ways.

C: What are the passive things you can do?

K: Well passive solar rays are not common to use at least in Finland. Only by using that as a heat source could give you savings up to 10-30% in heating energy demand. It means that you optimize the uptake of solar energy inside the building.

You for instance orient the building towards south, you make at least 50% of the windows facing south. You should also choose a window type where the G value, the solar factor coefficient, is high enough to let the solar radiation go through. If you do not fulfil these three things you will not get the benefits. In summertime, you need to have a shading structure that are dimensioned so that it cut steep angles. You can also lower the inside temperature, just 1 degree will give you a lot of savings. Dividing the building into heating zones is another good option. You are having spaces where you absolutely need to keep the room steady plus 21 or 20 but then you might have spaces where it can float a bit between 18-23.

C: Is there a manual way to ventilate a passive house?

K: The air circulation is done by a ventilation system. The idea is that there are no uncontrolled leakages of air. These ventilation systems are usually mechanical. So in a passive building you have a mechanical ventilation system always with heat recovery. If you are using natural ventilation then you will not reach those figures that are given for passive houses here in the north. Then you might have another sustainable solution but you cannot call it a passive house, even though it is a passive system.

C: Would you say that the mechanical ventilation is better than natural?

K: Well if you look energy-wise then the heat recovery is good. But if you look at for example how much buildings are dependent on electricity, how robust the systems are, then I think natural systems might be worth developing further. There will be higher energy consumption but the carbon footprint can still be quite low.

C: In the Nordic countries, which building materials are best for the overall structure and why?

K: If you look at energy consumption there are no big differences between the materials. There are small benefits of using massive materials but for example a floor slab of 8mm concrete is enough to give you some thermal storage.

C: I mean wood is noble because it can be recycled and it is a natural material but the concrete is in a way also good because it stands longer but then you cannot reuse it more than in road fills.

K: This is a fight the industry has had for years now. The way you calculate the carbon footprint today is specified in EN standards and they say that in a forest when wood is created and a tree grows, it absorbs CO₂ and then releases it in the end of its life and therefore it is considered neutral. So if you just take a tree trunk, if it falls naturally and you use it without any crafting it would be zero carbon. But already when you cut it with a chain saw and start sawing it then you start causing carbon footprint for wood material. The paradox is that the less you process wood the better is the carbon footprint. Among different materials, wood is a good choice. It depends on your design decisions.

C: So you would not suggest concrete or brick?

K: Well the most typical concrete uses a lot of Portland cement which is a quite big reason for CO₂ emissions. Even though they claim that it is beneficial to use concrete I would say that Portland cement is quite harmful to the environment.

C: So it is not even good in a longer term? Even though there is no maintenance needed?

K: Well we are now demolishing concrete buildings which are 30 years old, but if you can make them last 200 years then we start to talk about real benefits. But I think you can make a wooden house also last for 200 years. Bricks are made in a very energy intensive production but after that it can last for a really long time. I have been doing research on this and things are never black and white, they are not that clear as you might think they are.

C: Do you use green walls and roofs in your design for passive buildings?

K: Not for energy efficiency, but for other reasons yes. Usually the roofs are ventilated so under the green roof you have a ventilation cap so for that reason it does not really improve the thermal performance that much. We use it mostly to landscape the building. It also gives the roof a longer lifespan if it is a pitched roof because the solar radiation often destroys other roof materials. It is a wise strategy to use plants to control the micro

climate. Trees separated from the building are efficient to reduce the wind speed.

Passive house does not say anything about micro climate or the material that you should use. It is just a technical definition, numbers that you need to reach.

